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APPLE RUST

TECHNICAL BULLETIN

BY

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Ben Davis Apples, Showing Effects of Cedar Rust Infection.

APPLE RUST

INTRODUCTION.

The apple rust, or cedar rust as it is frequently called, is a common disease in most sections where apple trees and cedar trees are growing in close proximity. Before the habits of this fungus were very well understood it was a common practice to plant a row of red cedars along one or more sides of an orchard, to serve as a windbreak. The old time mixed orchard was likely to contain varieties which showed different degrees of susceptibility and, if the rust was present, those trees which suffered most from the disease were probably considered to be weaklings. Some of the trees were practically certain to bear well, which meant enough fruit for home use, and that was the principal object of such an orchard.

When people began to realize that there was good profit in growing apples for market they found that it was an easier proposition to handle a large number of trees of one or two varieties than a few trees each of several varieties. Certain apples were soon found to be well suited to a given section or sections of the country, and specialization set in. It happened that some varieties of apples especially susceptible to the apple rust disease were chosen as desirable for the planting of commercial orchards in sections of the country where red cedar was particularly abundant. (Plate IX, figs. 1 and 3.) Under such favorable conditions it must be expected that the amount of disease would increase.

In 1910 this rust was very severe in the eastern section of West Virginia and in 1912 the fruit loss, due to rust, in one county was estimated at not less than $75,000.00. This Department began some studies of the apple rust disease in 1910. Attention has been largely devoted to economic phases of the question, since it was of such great importance in this state.

NOTE: Mr. D. C. Neal, assistant plant pathologist during 1911-13, was associated with some of this work during the seasons of 1912-13.

HISTORICAL.

Gymnosporangium juniperi-virginianae was discovered and named by Schweinitz in 1822. The genetic connection between this and the *Roestelia pirata* of apple appears to have been finally worked out by Thaxter* in 1886. Since that time there have been numerous experiments dealing with the various phases of the cedar and apple rust problem. Of these, we will briefly mention the more important ones which have a bearing on the work conducted by this Station.

Halstead (1889, p. 380) says, "Very likely some varieties of cultivated apples are more susceptible to the rust than others, but as the observations upon this point are very meagre and fragmentary, it is not safe to draw general conclusions from them."

Galloway (1889, p. 413) reports on a spraying experiment for apple rust control at Vineland, N. J., in 1888. He states that the foliage remained fairly healthy, yet the benefit was not sufficient return for the labor expended.

Jones (1891, p. 139) conducted an experiment near Burlington, Vermont, in 1889. The trees were sprayed with ammoniacal copper carbonate May 17th and May 30th. The results showed no marked difference in the percent of rusted leaves, but the number of rust spots per rusted leaf were less on the sprayed than on the unsprayed trees.

Pammel (1891, p. 43) sprayed trees of the wild crab apple with Bordeaux mixture and ammoniacal copper carbonate. He concluded that there was little benefit from spraying.

Jones (1892, p. 133) reported on further experiments in the control of apple rust by spraying. He secured fairly good results, but did not feel that this method of control was very practical.

Jones (1893, p. 83) reported on the destruction of cedars as a means of controlling apple rust. He states that, "in the fall and winter of 1891-92 the red cedars were all destroyed in this orchard, and for a radius of one mile around a careful examination was made and every cedar found was uprooted. The result was magical. In former years many of the apple trees were entirely defoliated by rust in August; the past summer not a rusted leaf was found in the entire orchard. The

*This statement is based on Halstead, 1889, p. 375.

moral is plain. Red cedars should not be allowed to grow in or near an apple orchard. From the scientific standpoint the result is interesting as indicating that the mycelium of this fungus is not perennial in the apple, and that the occurrence of the rust on the apples is dependent upon annual reinfection from the red cedar." It should be noted, however, that the red cedar is not reported as a common tree in Vermont. While the trees were all destroyed within a range of one mile of this orchard, it is quite likely that very few of them could have been found within a radius of two miles.

Stewart and Carver (1896, p. 538) carried on a series of experiments to ascertain why the cultivated apple in central Iowa should be free from *Roestelia.* Inoculations with *G. juniperi virginianae* were made upon the wild crab, *Pyrus Coronaria*, and upon cultivated varieties at Ames, Iowa, and Long Island, N. Y. Abundant *Roestelia* developed on the wild crab but in no case was it formed on the cultivated varieties inoculated at Ames. The experiment at Long Island gave evidence that some varieties were wholly exempt from *Roestelia*, which indicated that its absence on cultivated apples in Iowa might not be entirely due to unfavorable weather conditions, but chiefly to the fact that the varieties grown in Iowa were not susceptible.

Austin (1901, p. 296) carried out the following spray program: Trees were carefully sprayed March 24th before growth started, again April 25th, May 4th, May 22nd, June 5th, June 20th, July 23rd, August 9th and August 28th. On October 10th the trees were examined and it was found that they were at least as badly infected as in the previous year.

Emerson (1905)* reports the results of a detailed spray program. Twenty-two trees of the variety Wealthy, and eight of Jonathan received from one to three applications of Bordeaux. The dates of spraying were April 26th, April 27th, May 7th, May 9th, May 23rd, and May 28th. Trees which were sprayed on May 7th or May 9th showed remarkable control.

Heald (1907, p. 219) discovered the biennial character of the fungus on the red cedar. He also carried out a series of spraying experiments to control the rust on cedar trees, and some very good results were secured.

*These statements in regard to Prof. Emerson are based on Pammel's report in Nebraska Agr. Exp. Sta. Bulletin 84, "The Cedar Apple Fungi and Apple Rust of Iowa," page 34.

Hein (1908) says, "Although spraying with Bordeaux mixture or other fungicides is sometimes recommended as a treatment for rust, we have experimented for three years without any markedly beneficial results."

Stewart (1910, p. 194) reports that Mr. F. A. Sirrine at Long Island has usually had little success in controlling rust in his bearing orchard by several applications of Bordeaux. However, in 1910, trees given two applications of 3-3-50 Bordeaux showed only one-tenth as much rust as the unsprayed trees.

Giddings (1911, p. 3) reports a case in which rust was well controlled by a single spray application.

Coons (1912, p. 217) carried on some experiments as to the development and discharge of sporidia. Speaking of the teliospores, he states that "The process of putting out germ tubes requires from 6 to 15 hours", but in our work we have secured abundant sporidia discharge within less than 3 hours after a sorus was moistened for the first time. (Plate II, figs. 1 and 2.)

Reed, Cooley & Rogers (1912, p. 7) state that various spray materials are being tried for control of rust, but that no entirely satisfactory spray has been found up to the present time. The same authors (1912 a) found that transpiration and carbon dioxide assimilation were greatly retarded in apple leaves which were infected with rust.

Bartholomew (1912, p. 253) reports the results of experiments for the control of this rust by spraying. Applications of Bordeaux mixture were made on May 15th, May 22nd and May 30th. He states that the spraying was done, "immediately following the formation on the cedar galls of the jelly-like telial extrusions," and "before sufficient time had elapsed for the transfer of the sporidia from the galls to the apple foliage." The trees so sprayed showed pronounced decrease in the percent of infected leaves. He concluded that, "The proper time for spraying cannot be designated by any fixed dates, for the crucial time for action depends entirely upon such weather conditions as favor the development of the cedar galls."

Giddings and Neal (1912, p. 258) found it possible to control this rust by spraying with lime-sulphur, Bordeaux mixture, or atomic sulphur.

Fulton (1913, p. 62) carried out some experiments on infection of apple leaves by rust. He concludes that, "Each leaf is most susceptible during a brief period only, in its development, and that at younger and older stages it is less susceptible or entirely immune." He says, "From the first swelling of the gelatinous horns to the formation of infection spores about 24 hours of moisture are required," but this must be an error since we have records of abundant sporidia discharge, under normal field conditions, within 6 to 8 hours after it first began to rain. (See page ~~14~~.) 19

Reed, Cooley and Crabill (1914) secured good results by spraying, but concluded that it was far more practical to destroy the cedar trees for ½ mile around orchards. They found a copper-lime-sulphur spray to be especially effective. This publication also states that, "The apple leaf is only susceptible to infection with cedar rust during its early period of development." They report a continuous discharge of sporidia for more than five days after a rain, but this hardly seems possible.

Reed and Crabill (1915, p. 180) report that respiration is increased in leaves which are infected with *Gymnosporangium.*

DISTRIBUTION.

This rust appears to be widely distributed through the central and eastern portions of the United States, and has been found in Ontario, Canada.

Rust on apple species has been reported from the following states:

Alabama	Louisiana	Ohio
Arkansas	Maine	Oklahoma
Colorado	Maryland	Pennsylvania
Delaware	Massachusetts	Rhode Island
Dist. of Columbia	Michigan	South Carolina
Florida	Minnesota	South Dakota
Georgia	Mississippi	Tennessee
Illinois	Missouri	Vermont
Indiana	Nebraska	Virginia
Iowa	New Jersey	West Virginia
Kansas	New York	Wisconsin
Kentucky	North Carolina	

DESTRUCTIVENESS.

As previously stated this disease has caused enormous losses to fruit growers in West Virginia. It was especially destructive in 1912 and the crop of York Imperial apples was an entire failure in many orchards. The trees were well loaded with fruit, but it was of such inferior quality that it hardly paid for the cost of picking. Actual fruit losses ranging from $2,000.00 to $3,000.00 per orchard, and due entirely to rust, were very common through the eastern portion of the state that season, while there were many smaller losses and some larger ones.

The injury resulting from apple rust is apparent in three ways: 1. The loss due to infected fruit. 2. Decreased size of fruit. 3. Loss of vigor of tree. Nearly all of the fruit infections take place in the calyx end, and this is not surprising in view of the fact that the apple is inverted, calyx end up, until about one month after blooming, and but comparatively few rust spores are disseminated after that time. During the time that the apple is in this inverted position the sporidia of the rust fungus find easy lodgement in the depression around the calyx or even in the so-called calyx cup, and moisture readily collects there so that conditions for their germination are almost ideal. Many diseased fruits find their way into the barrels, but they are more likely to be seconds than firsts, and a considerable number are so deformed as to be thrown in with the culls. (See frontispiece.) A large proportion of rusted fruits become infected with secondary rot fungi, and this entails much loss.

A question soon raised by apple buyers was whether or not the disease would spread in storage. While we were certain that it did not spread, no statements could be found in regard to it. In order that we might cite definite evidence along that line the following series of experiments was conducted:

A box was packed with 164 Ben Davis apples, 59 of which were rusted fruits, scattered among the healthy ones. In another box 57 rusted Ben Davis apples were mixed with 132 sound Rome apples. A third box was packed with 30 Rome, 23 healthy Ben Davis, and 53 rusted Ben Davis apples. The healthy Ben Davis and Rome apples were wounded with a sterile knife and a rusted Ben Davis was placed with the

diseased portion in contact with the wounded spots on the healthy apples. In a fourth box were packed 10 Ben Davis and 18 Rome apples each of which had been inoculated by placing a mature aecium in a slit in the flesh. In still another box were placed 31 rust diseased apples which showed no indication of aecia, and in the same box were packed 25 apples which had partially developed aecia. The surface areas of the rust spots on about 50 of these apples were marked off with india ink. All of the boxes were placed in cold storage at about 34° to 38° F.

The apples were placed in storage the 26th of November, 1910. They were examined January 31st, 1911, and May 18th, 1911. There was no indication of any vital activity on the part of the rust. No additional fruits developed rust; no aecia had developed; there was no change in appearance of partially developed aecia; and no increase in surface area on infected fruits. Cutting open such diseased apples, there was in many cases, a brown, somewhat corky layer surrounding the rust diseased tissue. There was considerable evidence of the activity of secondary fungi attacking the apples by way of these rust spots.

Other boxes of apples prepared and handled in the same way as those just described were placed in storage at 40° to 50° F. and the results were similar except that a greater amount of rot developed.

The second way in which the loss from rust becomes apparent is through the decreased size of fruits. In the case of infections which are at all severe the size of all the apples, sound as well as rusted, is reduced very appreciably. (Plate V, fig. 3.) More detailed statements in regard to this phase of the disease will be given under another heading.

The third injurious effect noted in diseased trees is the weakened vigor of the tree itself. This effect may persist to a very noticeable extent for at least two seasons after a serious outbreak of rust. It will be dealt with in more detail on another page.

PLATE I.

Fig. 1—Rust gall of *Gymnosporangium juniperi-virginianae* on red cedar, with mature teliosori. These sori have never been moistened. (About ⅔ natural size.)

Fig. 2—Same gall as shown at right in Fig. 1, but after moistening for about 3 hours. (About ⅔ natural size.)

Fig. 3—Mature teleutospores with pedicels. (× 240).

Fig. 4—Teleutospores taken 1 hour and 20 minutes after first moistening. Note early development of promycelium. (× 240).

Fig. 5—Teleutospores taken 1 hour and 45 minutes after first moistening a sorus. The promycelium is well developed. (× 240).

Fig. 6—Teleutospores taken 2 hours and 15 minutes after first moistening a sorus. The promycelium has divided into four cells with distinct walls and nuclei. (× 240).

LIFE HISTORY.

Gymnosporangium juniperi-virginianae is a heteroecious rust having the red cedar, *Juniperus virginianae*, and species of apple, *Malus*, as hosts. On the red cedar it appears in the form of corky galls, commonly known as "cedar apples." (Plate III, fig. 5.) In this latitude the galls first become apparent during June, continue to grow through the summer, and have almost reached maturity by late autumn. With the first warm weather of spring they develop numerous brownish projections known as sori. (Plate I, fig. 1.) Each sorus is composed of numerous two-celled teliospores more or less imbedded in a gelatinous matrix. (Plate I, fig. 3.)

Under favorable weather conditions, with sufficient moisture, these sori swell into large, finger-like projections. Each cell of a teliospore may then send out a promycelium. This promycelium quickly divides into four cells, each of which produces a secondary spore or sporidium. (Plate I, figs. 4 to 6.) As soon as the humidity decreases enough to cause appreciable evaporation the sporidia are forcibly discharged as stated by Coons (1912, p. 230)*.

The teliospores do not all germinate at once and sporidia may be discharged several times during the season. They are readily carried about by air currents and deposited on the

*The forcible ejection of sporidia was independently observed by the senior author during the spring of 1912. In a number of cases it was noted that there was an abrupt sidewise movement of the sporidium several seconds previous to its discharge. This movement was believed to indicate the rupturing of an outer wall or membrane at the base of the sporidium, but the studies were not made in sufficient detail to warrant any general conclusions.


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PLATE II.

Fig. 1—Teleutospores taken 3 hours after first moistening a sorus. Note sporidia formation. (× 240).

Fig. 2—Sporidia discharged upon slide 3 hours and 15 minutes after first moistening. (× 240). In several instances there was abundant discharge in less than 3 hours, but photographs were not secured.

Fig. 3—Mature rust spots on apple leaf. Upper surface view. (Reduced.)

Fig. 4—Upper surface of rust spot on apple leaf 16 days after inoculation. Note exudate from pycnia. (× 11.5).

Fig. 5—Upper surface of rust spot on apple leaf 20 days after inoculation. Exudation has ceased from most of the pycnia and they have turned black. (× 11.5).

Fig. 6—Pycniospores. (× 240).

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foliage of any nearby apple trees. Sporidia which find their way to the young foliage or fruit of susceptible apple varieties, under favorable weather conditions, will germinate and enter the host tissues.

The rust spots first become visible upon the upper surface of the leaves, and in about ten days after infection has taken place.*

At this time they are pale yellow spots about the size of a pin head. They assume a darker shade of yellow as they enlarge. (Plate II, fig. 3.) On some of the more susceptible varieties these spots sometimes become half an inch in diameter by the end of the season.

In about two weeks after the first appearance of the spots, little raised specks appear near the center of them. (Plate II, fig. 4.) These are the openings of the flask shaped pycnia. The sticky, dark orange exudate which may be seen on the rust spot at about this time contains the pycniospores. (Plate II, fig. 6.) As far as is known they have no important bearing on the life history of this fungus. Soon after the pycniospores have been discharged, the pycnia become apparent as small black spots. (Plate II, fig 5.)

On the lower surface of the spot, hypertrophy takes place, producing a swelling considerably elevated above the normal

*Our records show that inoculation made April 14, 1913, gave clearly visible spots in 16 days, while the infection which took place May 15th produced spots in 12 days. In 1914, the April 26th infection became apparent in 11 days and visible spots developed from the May 5th infection in 9 days.

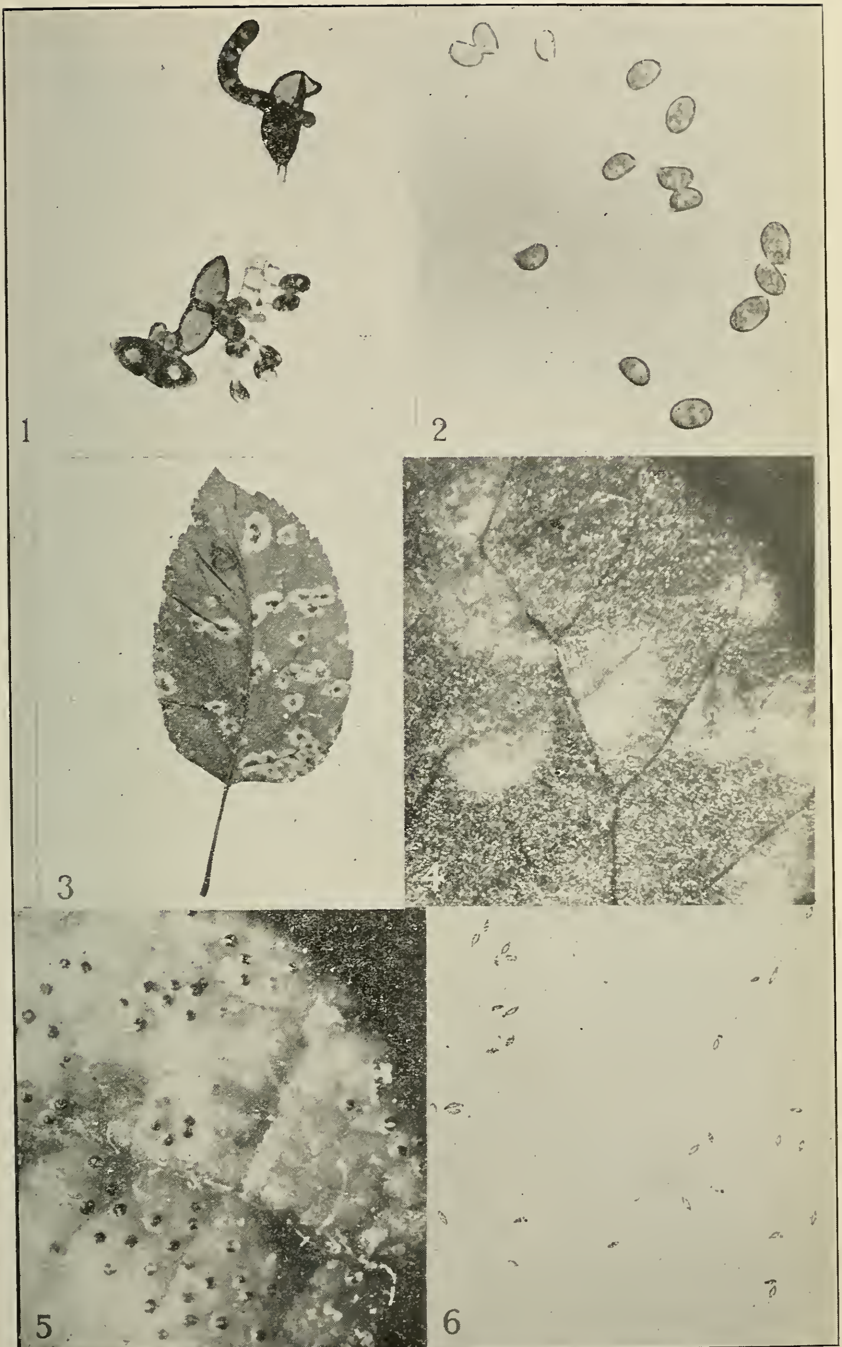
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PLATE III.

Fig. 1—Mature rust spots on apple leaf. Lower surface view. (Reduced.)

Fig. 2—Young aeciosori. Taken 64 days after inoculation. (× 5).

Fig. 3—Mature aeciosori. They are open and many of the aeciospores are gone. (× 11.5).

Fig. 4—Aeciospores. (× 240).

Fig. 5—Cedar twig with numerous galls of various sizes.

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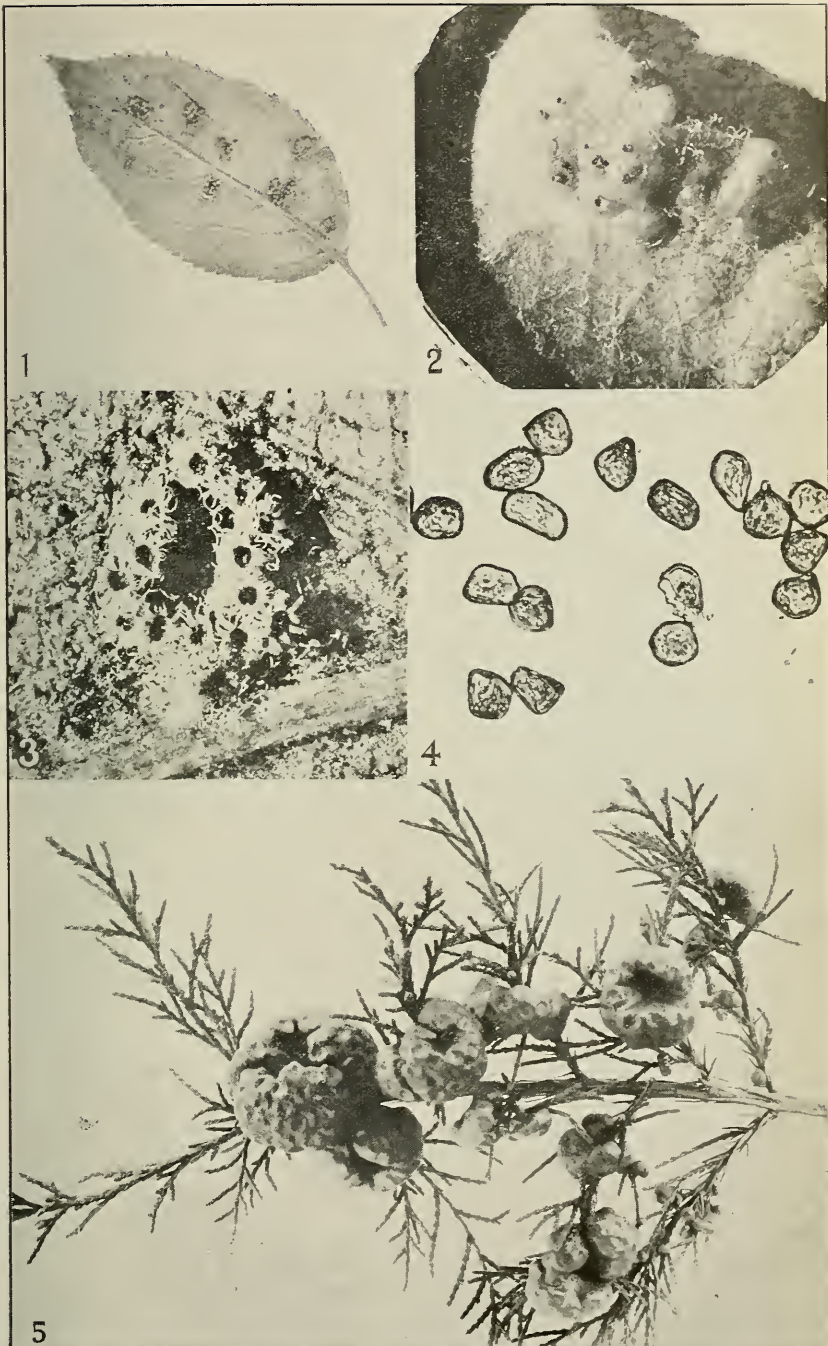
leaf surface. During the months of July and August bodies known as cluster cups, which bear the aeciospores, break through these swellings. (Plate III, fig. 2.) The aeciospores of this fungus are not capable of producing reinfection of the apple, but may be carried back to the cedar where they lodge in the axils of the tiny leaf scales, producing an infection in the young growth of the cedar. No outward indication of such cedar infection can be observed until the following season.

CONDITIONS INFLUENCING INFECTION OF APPLE.

It was believed that a more definite knowledge of the conditions which bring about rust infection of the apple under field conditions would be of value, and some attention has been devoted to this matter. These conditions readily fall under four main heads:

1. Development of rust galls on the cedar.
2. Meteorological conditions.
3. Development of apple foliage.
4. Location of orchard in relation to cedars.

The normal rust galls of *G. juniperi virginianae* as they occur on the red cedar in West Virginia are capable of discharging large numbers of sporidia at almost any time from the first of April to the first of June. This period varies considerably with different seasons, but the fruiting bodies are always well developed by the time that the apple buds begin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to open, and slight rust infections often occur as late as the first week in June.

The ability of the rust galls to produce and discharge sporidia is closely associated with meteorological conditions. Considerable difficulty was experienced in our endeavors to accurately determine the interrelation of meteorological factors with infection periods. Some general notes were made as to weather conditions during the season of 1912. These records were as good as could reasonably be secured under the circumstances. Data covering the critical period for that season shows that there was fair weather from the first to the fifth of May, a light shower on the afternoon of May 5th, fairly heavy rains from the afternoon of May 6th to the afternoon of May 8th, and fair weather from the 9th to the 11th. The important rust infection for 1912 took place between the evening of the 6th and the afternoon of the 8th of May. There was a slight earlier infection and another about the last of May or the first of June.

During the season of 1913 a barograph and a hygrothermograph were added to our meteorological equipment. (Plate IX, fig. 2.) This gave us a continuous record as to the temperature, humidity, and atmospheric pressure. Cold, rainy weather was prevalent most of the time from April 10th to 16th and considerable numbers of sporidia were discharged on the 13th. The recording instruments were not set up until April 14th so that we do not know the exact thermal and moisture conditions associated with the spore discharge on that date. It might be noted that there were very few apple leaves infected at this time and this is readily accounted for by the fact that measurements of a number of buds in different sections of the orchard on April 15th showed their average length to be only ⅜ inch to ½ inch.

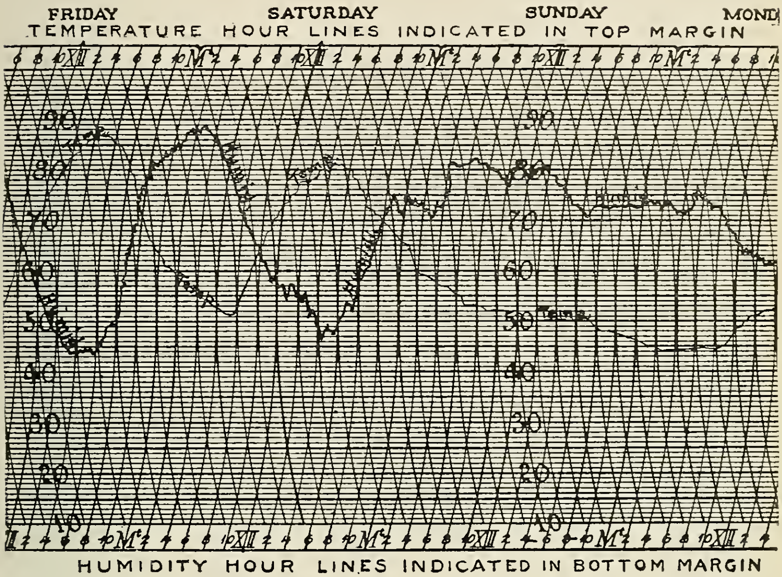
April 18th there was a thunder shower, but this had little effect on the cedar galls.

York Imperial apple trees were in full bloom April 25th and 26th.

April 27th there was an intermittent rain throughout the day and there had been some the preceding night, but there was no evidence of sporidia discharge or apple leaf infection as a result. The relatively low, and decreasing temperature which prevailed during that day and until ten o'clock the

next morning, may have prevented sporidia discharge, until the sori had dried up sufficiently to hinder it.

A section of the chart showing humidity and temperature for that period is reproduced below:



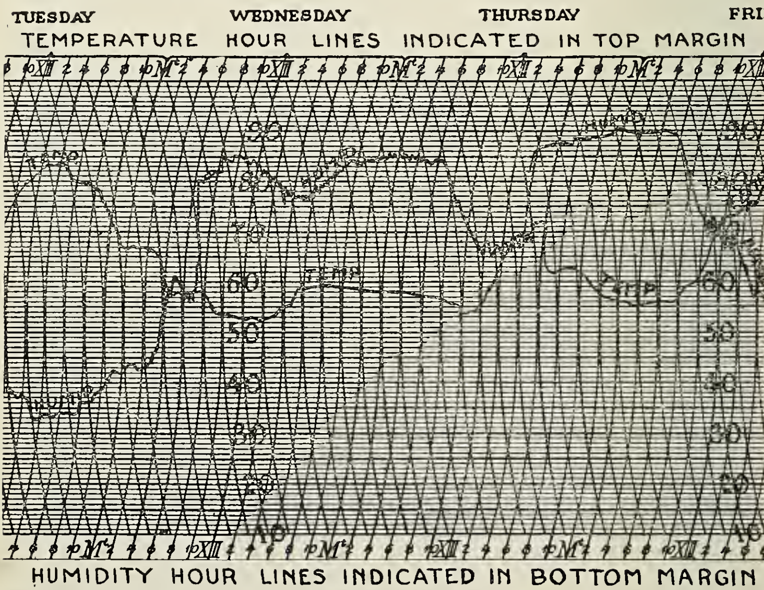
Hygrothermograph record from Friday, April 25th to Monday, April 28th, 1913.

There was no more rain until the morning of May 14th but it continued for about three to five hours at that time. In the afternoon it was cloudy and sporidia were discharged from the cedar apples in great numbers. White cards exposed just below good sized rust galls showed a very distinct yellow coating in two hours. There was no evidence of apple infection as a result of the sporidia discharge which took place that afternoon. Twigs of York Imperial apple trees that were covered with sacks on the morning of May 15th were as well protected from the rust as others right beside them which were sacked on the 14th. Conversely, twigs which had been previously sacked for two weeks to exclude rust infection and which were uncovered on May 14th, showed no more rust than similar twigs uncovered on the 15th. This can only be accounted for by the quiet condition of the air during the afternoon of May 14th. In the weather records covering that day it is stated as impossible to detect any air

stirring during the afternoon. It should be noted that these apple trees were within ten rods of large cedars which were literally loaded with rust galls.

It rained again during the night of May 14th-15th, and there was abundant sporidia discharge from about 10 A. M. to 2 P. M. of the 15th. The only serious rust infection for the season of 1913 occurred at this time. There was a light wind and it was somewhat variable.

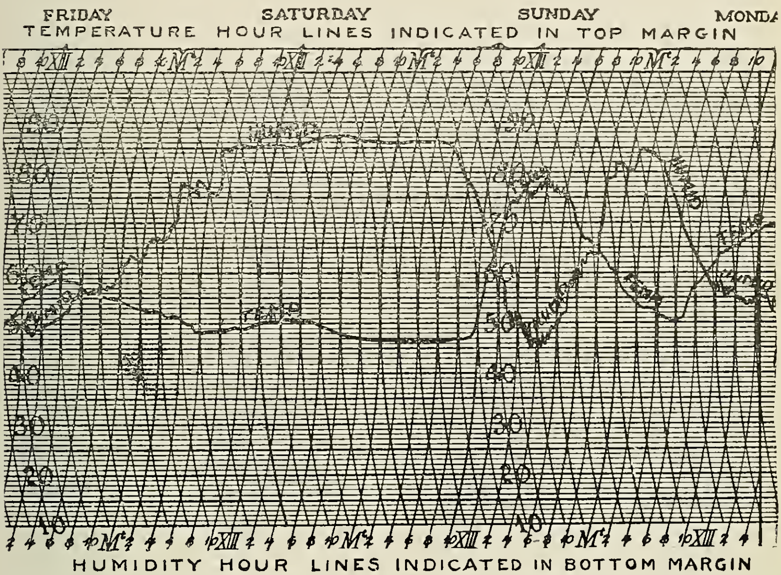
The humidity gradually dropped about 15% during the period of the most active sporidia discharge on May 14th, and there was a slight raise in temperature during that period. Similar data may be noted on the chart for May 15th, except that the drop in humidity was considerably greater and the rise in temperature was more pronounced than on the previous day. A section of chart showing tracings for May 14th and 15th, 1913, is shown below:



Hygrothermograph record from Tuesday, May 13th to Friday, May 16th, 1913.

Rain occurred again on May 17th, but there was no evidence of infection following it. Twigs which had previously been sacked and were uncovered on the 16th were as well protected as those uncovered on the 19th. The humidity and

temperature conditions would appear to have been very good for sporidia discharge, but we have no records as to air movements. It is possible that many sporidia were set free and that they settled quickly to the ground as on May 14th, but it is far more likely that only a very few were discharged, since the sori on the cedar galls were much reduced in size and evidently becoming exhausted. Careful observations as to actual spore discharge were not made on this date. The section of chart for May 17th and 18th is given below:



Hygrothermograph record from Friday, May 16th to Monday, May 19th, 1913.

Local showers occurred on the 21st and 22nd, but were of short duration, and did not have much effect on the cedar galls. May 23rd there was rain all day, but the hygrothermograph records covering that date are incomplete, and no special observations were made as to discharge of sporidia. It is worthy of note, however, that there was a light west to northwest wind recorded for the 23rd and 24th and our sacking experiments gave strong evidence that no infection took place on these dates.

It began raining again on the evening of May 26th and continued most of the time during that night and the next day A very considerable number of apple leaves became in-

PLATE IV.

Cedar tree bearing a great number of good sized galls.

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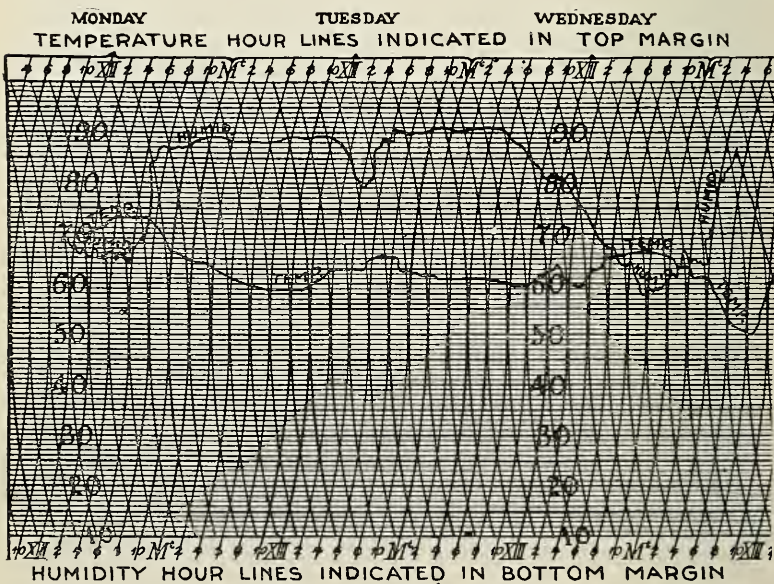
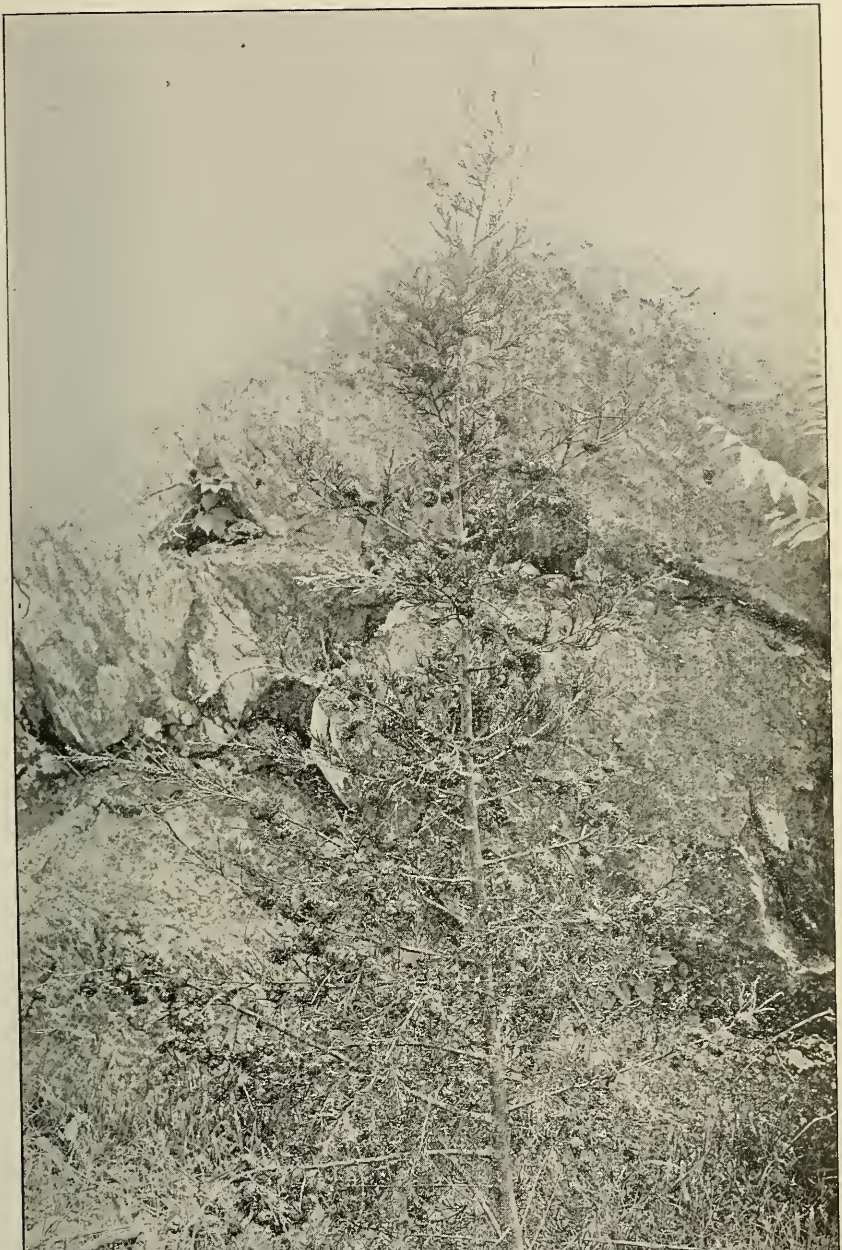
fected with rust on the 27th and possibly a few received infection on the 28th. It is believed that the principal and possibly the only sporidia discharge took place between 4 and 7 P. M. on Tuesday, the 27th. A drop in humidity and a rise in temperature will be noted for that period in the chart below:



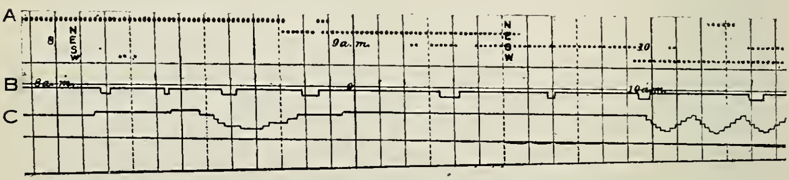
Hygrothermograph chart from Monday, May 26th to Thursday, May 29th, 1913.



Practically all of the sori dried up and dropped off from the cedar galls soon after this date and no further observations were made on them.

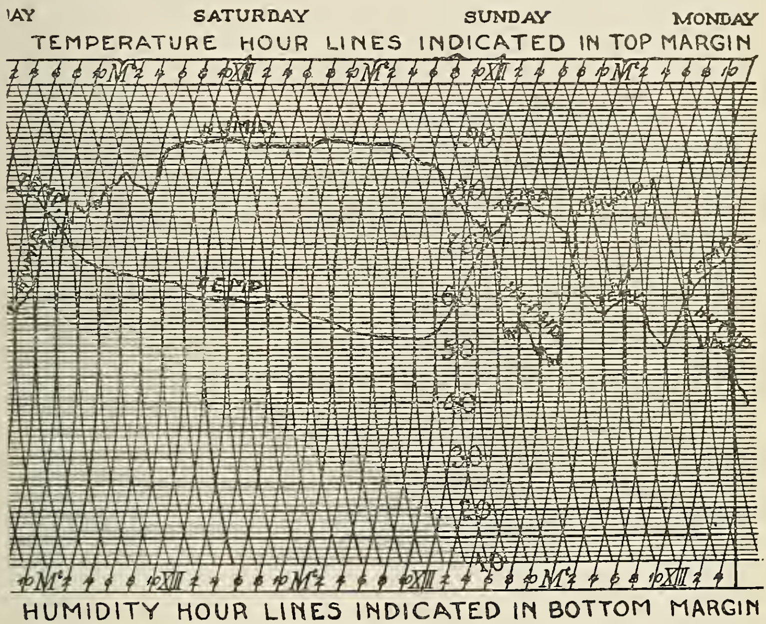
The importance of the wind in dissemination of rust, and the difficulty of making accurate observations along this line, was clearly shown by the work during 1913. In order to secure such data our meteorological equipment was again increased by securing a quadruple register, tipping bucket rain gauge, electric sunshine recorded, anemometer, and wind vane. (Plate X.) This outfit gave almost continuous records as to rainfall, sunshine, wind velocity and wind direction. The practical data secured with the aid of these instruments during the past season is very valuable, and careful observations continued for the next few years should yield reliable information of very great value in connection with the study of this disease, and possibly of others. Our records for the growing season of 1914 begin with April 23rd and are very nearly complete. The clock in the hygrothermograph was permitted to run down at the time when one rust infection was taking place; and two of the hygrothermograph records have been lost.

There was no rain from April 21st to April 25th. It began raining the morning of April 25th and continued intermittently all day. This was followed by very heavy showers in the evening and a steady rain which lasted until 9 A. M., April 26th. Sporidia were discharged in great numbers between 9 A. M. and 12 noon on Sunday, April 26th. The quadruple register records for this period of spore discharge show a variable wind having a general southeast to southwest direction; an average wind velocity of about four miles per hour; and continuous sunshine after 10 A. M. Sections from this chart are shown below:



Sections of quadruple register chart showing wind direction, wind velocity, rainfall, and sunshine from 8 A. M. April 26th, to 10:30 A. M. April 26th, 1914. A, indicates wind direction; B, wind velocity; C, rain until 9 A. M. and sunshine after 10 A. M.

The hygrothermograph record shows a rather rapid fall in humidity and an equally abrupt rise in temperature. The section of the chart for Saturday, April 25th and Sunday, April 26th is given:



Hygrothermograph record from Friday, April 24th to Monday, April 27th, 1914.

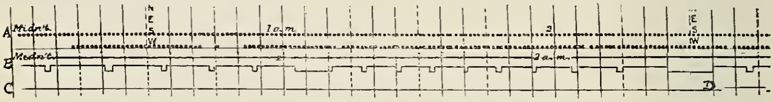
A general infection of apple foliage took place at this time, but it was not serious because there were only a few leaves unfolded. The blossom buds were just beginning to show color on April 26th and the central blossom did not open until May 1st. The leaves which enclose the blossom cluster were opened out sufficiently to receive infection and it was very noticeable on all of the trees sprayed May 4th that the leaves which came from a fruit bud were all quite heavily infected while those from a leaf bud did not show as much rust. Twigs covered with sacks on the afternoon of April 26th and uncovered on May 10th showed the extent of this infection.

It should be noted that a very light wind was sufficient to disperse the sporidia.

A shower occurred on the afternoon of April 29th, but did not have much effect on the cedar galls.

There was a shower about 5 P. M. on May 4th, and this was followed by a light rain from 6:30 P. M. to 11 P. M. The hygrothermograph record covering May 4th and 5th showed a drop of 10 to 15% in humidity between midnight and 2 A. M. May 5th. It began raining again at about 2:30 A. M. May 5th and continued until 10 A. M. of the same day.

Sections of the record from the quadruple register are given below:



Sections of quadruple register record from midnight May 4th to 2:45 A. M. May 5th, 1914. A, indicates wind direction; B, wind velocity; C, sunshine line; D, rainfall.

York Imperial twigs sacked immediately after it stopped raining on the morning of May 5th were just as badly diseased with rust as unprotected twigs on the same tree. Trees sprayed about 11 A. M. that day showed just as much rust as unsprayed trees. The sporidia discharge had occurred between 12 and 2:30 A. M. May 5th and the infection of apple foliage and fruit had evidently taken place at once. The wind which carried the sporidia was in a general southwest direction, varying to south and with a velocity of about ten miles per hour. Infection was general and quite severe.

There was no evidence of sporidia discharge during the forenoon of May 5th, although careful observations were made by exposing large watch glasses near the cedar galls for from one to six hours. The sporidia, if discharged in any numbers, would alight on the watch glass, and their presence could easily be detected with a microscope.

On May 8th it rained from about 8:30 A. M. until 12:30 P. M. and there were showers during the latter part of the afternoon and until 7:30 P. M. Sporidia were discharged during the night but there was no evidence of infection occurring at this time. The wind direction was extremely variable during the night of May 8th and 9th and its velocity was only 1½ to 2 miles per hour. It is probable that the sporidia dropped to the ground before they had been carried far from the sori which produced them.

There was another shower late in the afternoon on May 12th, but it was of short duration and no sporidia discharge

was noted. Light showers occurred on May 28th, 30th, and 31st, but no evidence of sporidia discharge or infection was noted as a result. The humidity ranged very low throughout the period from May 12th to June 4th and the temperature was comparatively high most of the time.

It rained during the forenoon of June 4th, and beginning again at about 4 P. M. that day, it rained intermittently all night. There was a slight, but rather general infection of apple rust at this time. The wind direction was south varying to southwest, but both wind velocity and humidity records covering this period happened to be incomplete.

The sori on the cedar rust galls were nearly exhausted by this date, and there was no further evidence of sporidia discharge or infection.

These observations and records have not been continued for a sufficient length of time to warrant drawing definite conclusions as to the exact relation of meteorological factors to sporidia discharge and infection. A few points which seem particularly worthy of mention are: (1) That, so far as our records go, there has been a drop in humidity every time that sporidia have been discharged; (2) That the sori appear particularly active after a prolonged dry spell, and seem to be temporarily exhausted by two or three closely successive sporidia discharges: (3) That there may be a very heavy discharge of sporidia without any general infection of apple foliage or fruit: (4) That an infection may take place during the night, under conditions which would have proven very deceptive and confusing without careful and exact records. Such an infection occurred the night of May 4th to 5th, 1914.

The development or stage of growth of the apple foliage is a very important factor in determining the amount of infection. Under West Virginia conditions many sporidia are likely to be disseminated before the leaves have unfolded sufficiently to receive infection. Careful field and laboratory experiments have shown that natural infection may take place on York Imperial leaves just as soon as they have unfolded enough to expose any portion of their upper surface,* although this does not agree with Fulton (1913, p. 64.) Inoculation experiments conducted in 1914 gave no infection on the lower

*From our experience, we are inclined to believe that the inoculation of very young leaves may be accomplished to better advantage by carrying the freshly discharged sporidia on to the leaf in an air current, rather than by using liquid suspensions.

PLATE V.

Fig. 1—Rust galls of various sizes with expanded, gelatinous sori. Note small galls on single needles at right. (About natural size.)

Fig. 2—Larger rust galls with expanded, gelatinous sori. (About natural size.)

Fig. 3—Apples from trees with one side rust infection in 1912. The two at right were largest on side which showed least infection, while the two at left were largest on badly infected side. Collected about August 1, 1912.

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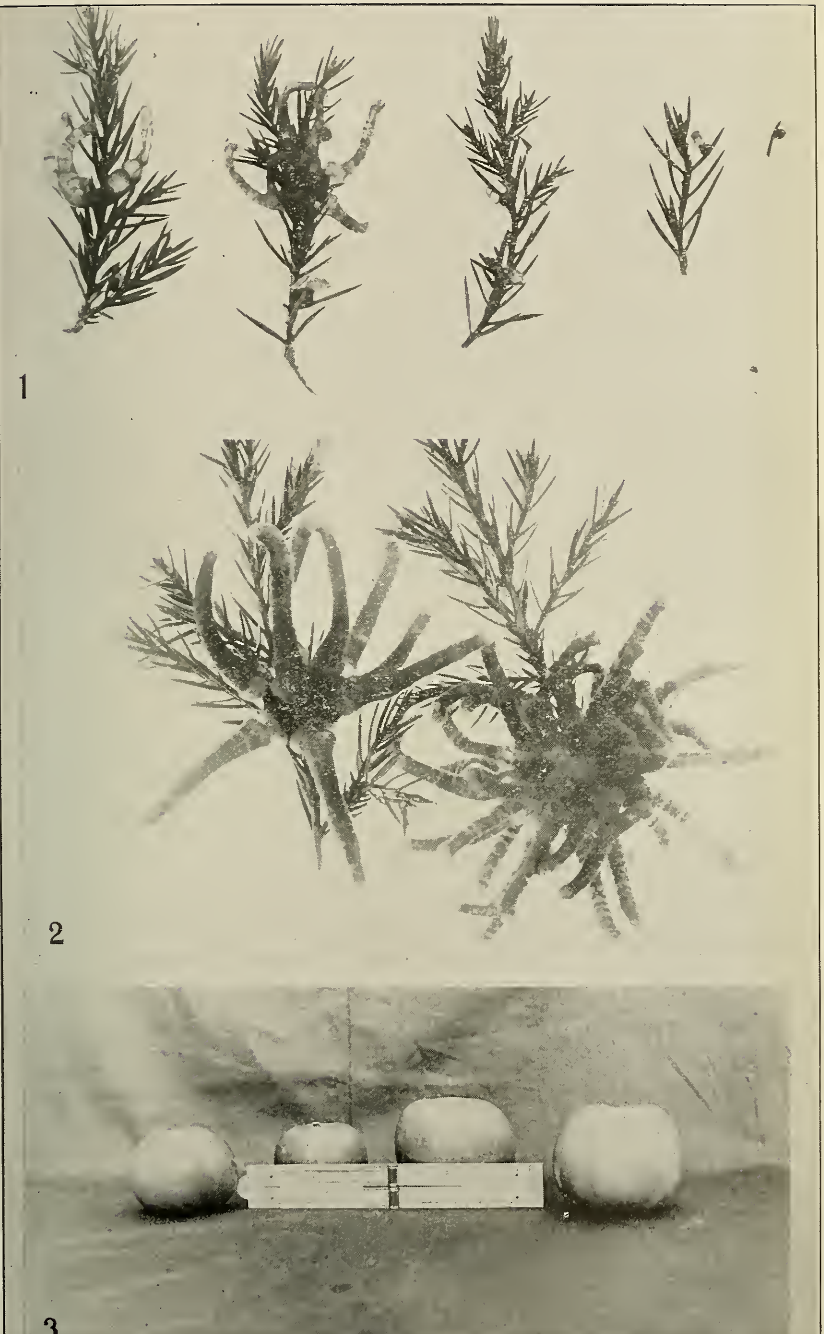
leaf surface, as was reported by Coons (1912, p. 221). Sporidia in suspension were used for this work, and good infections were secured on upper leaf surfaces under the same conditions. Inoculation experiments early in the season of 1912 and repeated in 1913 gave severe infections of leaves which were just beginning to unfold. These inoculations, however, were made by gently rubbing the young leaves with gelatinous teliosori.

The gradual development of resistance, or immunity in the leaf is very striking and extremely important, and Reed (1914, p. 15) gives some records of it. There were two rust infections in 1911. We do not know the exact dates when they occurred, but one was probably just as the first blossoms were about to open and the other not until the latter part of May. The terminal growth on York Imperial twigs during that season commonly showed nine large leaves. The first three and last three leaves on such a growth were rust infected, while between them were three leaves free from rust. This was very noticeable, and was commented upon by many orchard men. The fourth, fifth and sixth leaves must have been immune at the time that the three youngest leaves were infected.

The same thing is clearly shown in Table XII. At the time when the important infection took place in 1913, the first three to five large leaves had become immune. Table XV indicates this in relation to the June 4th and 5th infection of 1914.

Stewart (1910, p. 317) says, "The spring of 1903 was very dry at Riverhead, Long Island. There was no precipitation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of any importance between April 16th and June 8th. As a consequence, there was no opportunity for the infection of apple leaves until June 8th and 9th on which dates there were heavy showers and the cedar apples became swollen into yellow gelatinous masses of unusually large size. Very little rust occurred on the leaves that year." Evidently most of the leaves had become immune when that infection occurred.

During 1914, records were kept on several twigs showing the exact date when each leaf finally opened out from the bud. From the data for this season it would appear that a leaf was immune ten days after unfolding. The exact time required for a leaf to develop to the same extent during another season or under other conditions, might vary somewhat from this period.

The points to be emphasized are that the leaves do become immune, (due evidently to a thickening and hardening of the epidermal cells, as well as to other chemical and physical changes in the interior of the leaf), and that a rust infection of destructive proportions can hardly be expected to occur after June 1st, under West Virginia conditions.

A mature leaf may occasionally become infected through insect injuries Successful inoculations have also been made in mature leaves which were torn or injured by needle punctures. Infections of this kind develop very small spots, and aecia production has never been noted from them. They are not likely to be of economic interest.

The relative locations of orchards and cedar trees form an important factor in connection with rust epidemics. Obviously, a cedar tree has much better opportunity for effective dispersal of rust sporidia when it is located on ground higher than that of nearby apple orchards. These sporidia act much like grains of pollen or particles of dust when they are in the air. The distance to which they may be carried is largely dependent upon the wind, but the comparative elevation from which they start, and objects which may intercept them, must also be considered. McCarthy (1893, p. 86) states that mature spores may be carried for four miles in an unusually high wind. Thaxter, (1891, p. 3) says, "Although it has been shown that infection from cedars may take place at a distance of eight miles, the virulence of the disease is, of course, proportionate to the proximity of the cedars." It is

quite probable that freshly discharged sporidia are carried as far as eight miles in a high wind, but rarely, if ever, would other conditions be so favorable as to produce an infection of economic importance at that distance from the cedars.

INFECTION OF CEDAR TREES.

The question has sometimes been raised as to how far an infection will be carried from the apple to the cedar. Before discussing this point, it should be stated that there appears to be very little known in regard to the exact manner of cedar tree infection, and the conditions which bring it about. The aeciospores, produced on apple foliage and fruit, are considerably larger than the sporidia, and presumably weigh more. Under the same conditions, we would not expect the aeciospores to be carried as far as the sporidia. Now, it would appear that, if the amount of rust infection in an apple orchard is appreciably reduced by cutting out the cedars for possibly one-fourth mile around it, the amount of infection which would be carried back to the cedars would be reduced in even greater proportion.

There are many reasons why this cannot be expected to work out in actual practice. The four reasons which we think to be most important are: 1. The presence of wild crab, seedling or neglected common apple trees near or among the cedars. 2. The presence of small orchards, and what might be termed door-yard apple trees in the close vicinity of the cedars. 3. The probability that the total period during which aeciospores are distributed is very many times greater than the total period of actual sporidia discharge. 4. The great variation in meteorological conditions. There are several important factors, such as wind and rain which would be considered under reason No. 4, and some others closely related to or associated with these factors, but it hardly seems best to enter into an extended discussion of these matters.

PHYSIOLOGICAL EFFECT OF RUST ON APPLE TREES.

A question raised early in our work on this disease was as to the effect of rust on the general health of an apple tree. It was believed that the injurious effects of a serious rust infection would persist during the season following such an outbreak. There was very little evidence at hand in regard

PLATE VI.

Fig. 1—Apple tree which suffered from one sided rust infection in 1912. Picture taken May 3, 1914. Note bloom on side which had least rust in 1912.

Fig. 2—Eleven year old York Imperial apple tree which has suffered from many severe rust infections.

Fig. 3—Eleven year old York Imperial apple tree which has not been a severe sufferer from rust infections.

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to this, and it appeared difficult to secure it since the infection is so general that all the trees of any one variety in a given section are likely to show nearly the same amount of disease.

Two orchards were finally found which may serve for some general comparisons. These orchards were less than two miles apart and will be designated as No. 1 and No. 2. The trees chosen for comparison were of the same variety, York Imperial, and the same age, 11 years. Orchard No. 1 had received good care, and happened to be so situated as not to have suffered from very severe infections of rust. One of the trees in this orchard is shown by Plate VI, fig. 3. This tree was growing under soil and drainage conditions as nearly comparable as possible with those of orchard No. 2. Orchard No. 2 had received what might be called fair cultural attention. It had been plowed, fertilized, and sprayed, but not quite so systematically and carefully as orchard No. 1. This orchard was not over ten or fifteen acres in area and there were cedar trees within two rods of it on every side. There were quite a number of large cedar trees, twenty to thirty feet high, within ten to twenty rods of the orchard, and many small cedars on all sides. In 1913, when particular note was first taken of this orchard, the cedar trees around it were practically loaded down with rust galls. A typical York Imperial tree in orchard No. 2 is shown by Plate VI, fig. 2. There were about equal numbers of York Imperial and of Ben Davis apple trees in the last mentioned orchard. The trees of both varieties were the same age and had received the same care, but the owner reports that the York Imperial trees have not borne more than an average of three


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apples per tree while the Ben Davis trees have borne an average of three barrels per tree. The Ben Davis trees, right beside the York Imperials had made good growth. They were at least two-thirds larger than the York Imperial trees and appeared very healthy.

It seems safe to conclude that the lack of development of the York Imperial apple trees in orchard No. 2 was largely the effect of the serious rust infection recurring each year.

Another case which seems worthy of mention is that of some trees showing a far more severe infection on one side than on the other. This one-sided infection took place in 1912. The trees were York Imperial, about 12 years of age, in rows along the top of a ridge. There was a considerable number of cedars in the vicinity of the orchard, and a large grove of them a little way down on one slope of the ridge. A strong wind was blowing from this grove into the orchard at the time of infection, and the effects of the disease appeared to be at least twice as severe on the side toward the cedar grove as on the other side. On the side where infection was greatest, the apples were not more than two-thirds as large as those on the other side. (Plate V, fig. 3.)

In the spring of 1913 this orchard was visited and it was found that the trees which showed the one-sided rust infection in 1912 were not blooming at all on the side where the disease was so severe, while there was a very fair amount of bloom on the other side. No good photographs of the trees were secured at that time. A late spring frost destroyed all of the young fruit which had set on these trees, and it was believed that they would entirely recover to their normal condition by the following spring.

The orchard was visited again the spring of 1914, and evidences of the one-sided rust infection were still visible in the first four or five rows of apple trees extending along the top of the ridge. Quite a little individual variation in the trees could be noted, but there was a very clear difference between the two sides. The bloom was slight or scattering on the side where rust infection had been severe, and was very profuse on the other side. (Plate VI, fig. 1.)

The trees in question may have suffered from one-sided rust infections previous to 1912, but evidence from observation, or from the development of the trees, does not indicate

that such was a regular, or even frequent, occurrence. It should be noted that all cedars in the immediate vicinity of this orchard were destroyed during the winter of 1912-13 and that the radius of cedar-free territory was extended during the winter of 1913-14. Whatever rust infection took place in this orchard during the past two seasons was very uniformly distributed and can have had but little effect upon the one-sided fruit production of the trees in question.

Spraying experiments, conducted in 1912*, prevented serious rust infection on portions of certain York Imperial trees in one orchard. The only York Imperial bloom observed in this orchard in 1913 was on the parts of trees where rust had been controlled the previous season. It was also observed in 1913 that these portions of trees retained their foliage longer than unsprayed portions of the same tree and longer than any unsprayed trees in the orchard. Their condition was not noted in 1914.

Spraying experiments were again conducted in 1913 but practically all of the young fruits were destroyed by late frosts and general rust infection was not so severe as in 1912. The number of leaves showing rust spots and the number not so diseased were determined on one or more twigs of each tree used in these experiments. This count was made about June 10th and the two small leaves, which unfolded first, were removed before counting. The leaves were again counted during the first week in October, and from this count it was possible to determine the number of rusted leaves which had fallen as compared with the number of rust-free ones which had fallen. The results are briefly summarized in the following table:

Table I.—*Leaf fall as affected by rust in 1913.*

	No. leaves in June	No. leaves in October	No. leaves fallen	Percent fallen
Rusted	657	135	522	79.4
Rust-free	943	522	421	44.6
Total	1600	657	943	58.9

This table includes counts from ten trees chosen at random from among those upon which rust had not been controlled. Detailed tables might be given, but they would show little more, and the data for 1914 will be of more interest and

*The 1912 experiments were conducted in an orchard owned by D. Gold Miller at Gerrardstown. The 1913 experiments were conducted in the orchards of Hon. George M. Bowers, and B. Frank Mish at Inwood. The 1914 experiments were conducted in the orchard of Dr. A. P. Thompson at Summit Point. Acknowledgement is due these gentlemen for their courtesy to us in connection with this work.

PLATE VII.

Fig. 1—York Imperial apple tree upon which rust was controlled by spraying in 1913.

Fig. 2—York Imperial apple tree upon which rust was not controlled in 1913. This tree is just adjacent to the one shown in fig. 1.

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value along this line. The effect of rust control upon leaf fall in 1913 is indicated by Plate VII, figs. 1 and 2.

During the season of 1914 this phase of the work was enlarged to include the location of each leaf in regard to order of opening from bud, and the number of rust spots on each leaf as well as the number of leaves. The two small, oldest leaves were removed before counts were made. These detailed field counts were made on twenty-five trees, and included about 320 leaf clusters, of which one-half were terminal growths of twigs. Ten of the trees were unsprayed, five had been sprayed with lime-sulphur, five with Bordeaux mixture, and five with atomic sulphur. The rust was quite well controlled on the sprayed trees.

A sample page of the records on these leaves is shown:

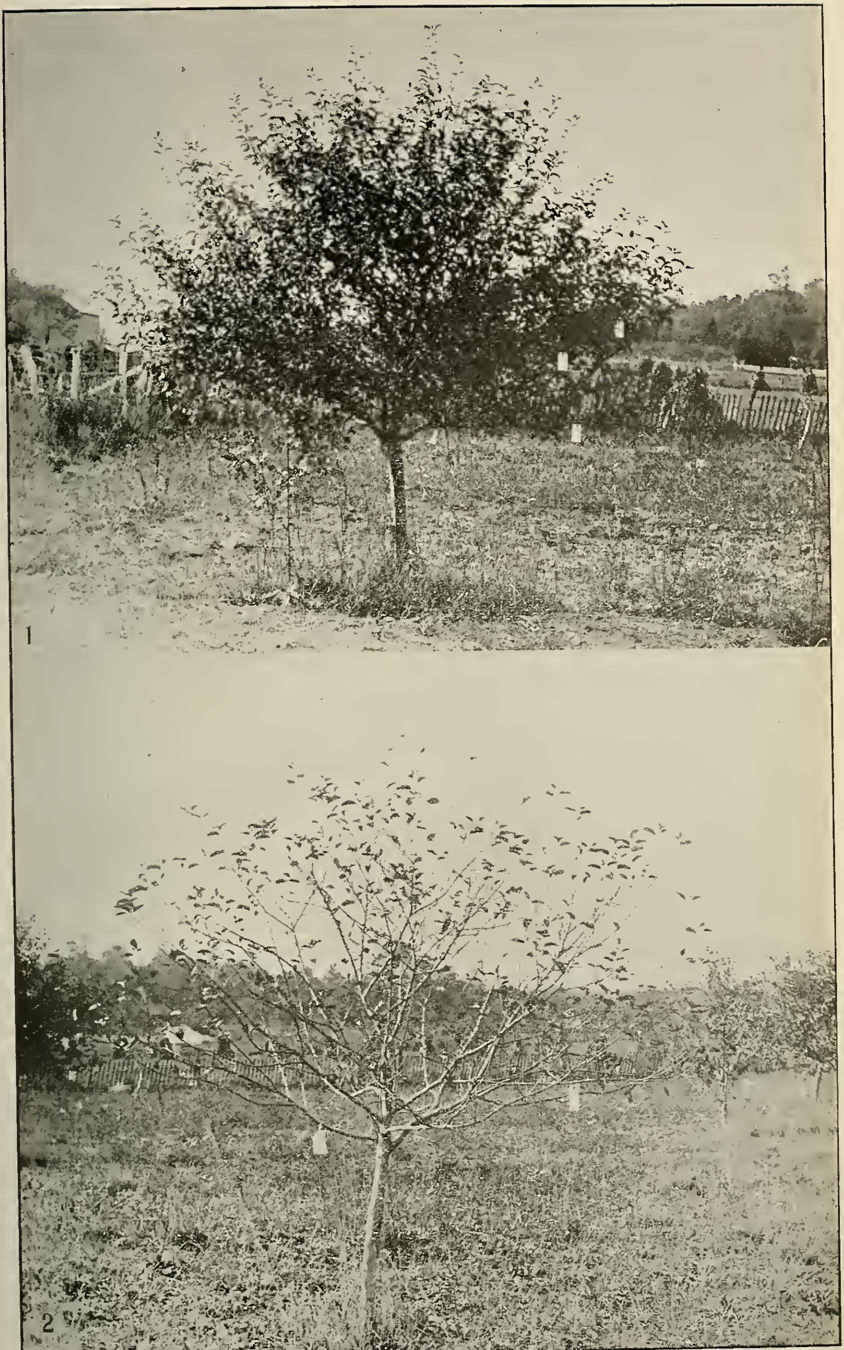
TREE NO. 323. TWIG NO. 2—CHECK. (See footnote *)

TREATMENT—LIME-SULPHUR—BLOCK F.

	No. of leaf†	1	2	3	4	5	6	7	8	9
Terminal Growth	Rust spots	9	22	9	4	0	0	0	0	8
	Date fallen	7-30	7-30	10-3	10-30		10-30			10-3
Side Spur No. 10	Rust spots	8	17	16	0	0	0			
	Date fallen	10-3	7-30	10-3	7-30					

*This was a *check* twig on a *sprayed* tree.
†Leaf No. 1 is the oldest.

The data from these records has been carefully tabulated and is given in condensed form as Table II. This table is arranged to show the number of leaves having one rust spot,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the number having two rust spots, etc. It also gives the number of such leaves which had fallen between specified dates. For example, there were 137 leaves having two rust spots each. Six of these leaves fell between July 6th and August 1st; four between August 1st and September 1st; 22 between September 1st and October 1st; and 30 between October 1st and November 1st. There were 62 of these leaves which dropped between July 6th and November 1st, 1914, and 75 leaves, each showing two rust spots, still remained upon the twigs. The first counts were made July 3rd to 9th, and some of the badly rusted leaves had already fallen at that time. Counts were again made July 28-30, August 27-30, October 2-5 and October 30-31.

TABLE II.—*Leaf fall as influenced by the number of rust spots per leaf.*

Number spots on each leaf	Number of leaves	Number of leaves fallen by periods				Total number of leaves fallen	Number of leaves on twig Nov. 1.
		July 6 to Aug. 1	Aug. 1 to Sept. 1	Sept. 1 to Oct. 1	Oct. 1 to Nov. 1		
0	832	23	9	45	122	199	633
1	266	6	6	39	65	116	150
2	137	6	4	22	30	62	75
3	75	5	2	13	12	32	43
4	82	6	0	16	20	42	04
5	56	2	6	14	10	32	24
6	60	7	3	16	13	39	21
7	47	7	3	12	8	30	17
8	39	4	3	12	9	28	11
9	29	3	1	12	3	19	10
10	28	2	3	10	4	19	9
11	21	4	3	5	5	17	4
12	25	5	6	9	3	23	2
13	26	2	1	15	3	21	5
14	26	7	4	11	2	24	2
15	27	3	5	10	6	24	3
16	23	7	2	8	3	20	3
17	25	7	5	7	3	22	3
18	21	5	5	4	6	20	1
19	17	3	2	11	0	16	1
20	16	2	2	9	2	15	1
21	23	9	6	5	3	23	0
22	18	6	2	7	1	16	2
23	13	3	1	6	3	13	0
24	23	12	5	4	2	23	0
26	29	12	8	8	1	29	0
28	29	11	11	7	0	29	0
30	28	11	10	3	4	28	0
33	33	10	11	12	0	33	0
36	26	5	15	4	2	26	0
40	29	8	13	6	2	29	0
45	28	9	13	6	0	28	0
50	13	8	4	1	0	13	0
55	17	7	7	2	1	17	0
60	10	7	2	1	0	10	0
over 60	23	13	7	2	1	23	0
Totals	2220	247	190	374	349	1160	1060

It should be possible from this table to get an indication as to how quickly and how seriously a York Imperial apple tree is likely to be defoliated by a certain amount of rust infection on the leaves. In order to bring out this point, we have further condensed Table II by dividing the leaves into five groups, those having no rust spots, those having one to four rust spots, those having five to nine rust spots, those having ten to fourteen rust spots. The results thus secured are shown below:

TABLE III.—*Leaf fall as influenced by number of rust spots per leaf.*

Number of rust spots per leaf	Number of leaves	Number of leaves fallen by periods							
		July 6 to Aug. 1		Aug. 1 to Sept. 1		Sept. 1 to Oct. 1		Oct. 1 to Nov. 1	
		No.	Percent	No.	Percent	No.	Percent	No.	Percent
None	832	23	3.8	9	1.1	45	5.5	122	14.8
1 to 4 inc.	560	23	4.1	12	2.1	90	16.1	127	22.7
5 to 9 inc.	231	23	10.	16	6.9	66	28.5	43	18.6
10 to 14 inc.	126	20	15.9	17	13.5	50	39.7	17	13.5
15 or more	471	158	33.5	136	28.9	123	26.2	40	8.5

Number of rust spots per leaf	Number of leaves	Total fallen July 6 to Nov. 1		Left on tree Nov. 1	
		No.	Percent	No.	Percent
None	831	199	24.2	633	75.8
1 to 4 inc.	560	252	45.	308	55.
5 to 9 inc.	231	148	64.	83	36.
10 to 14 inc.	126	104	82.6	22	17.4
15 or more	471	457	97.1	14	2.9

Normal leaf fall was beginning to increase by the latter part of October, so that the more important results are to be found between the dates of July 6th and October 4th, or October 1st as given in Table II. It may be readily determined that the number of leaves fallen on October 1st is closely proportional to the number of spots per leaf. This applies particularly to leaves having from one to nine spots, where the original numbers of such leaves were large enough to be fairly compared.

Additional tables might be given to show the results from sprayed and unsprayed trees, but they would indicate little that is not already shown in Table II. The sprayed trees, of course, have fewer rusted leaves, and comparatively more leaves with a small number of spots per leaf, but the percent-

age of leaf fall appears to be fairly constant for leaves showing a certain number of rust spots.

One other condensed table may well be included to show the effect of rust on foliage retention during the season of 1914. This table, No. IV, includes records from 58 trees and about 300 twigs. The data already given for 1914 is included.

Table IV.—*Leaf fall as affected by rust in 1914.*

No. trees included	18	18	23	9
Treatment	atomic sulphur	Bordeaux	lime-sulphur	check
No. leaves counted	4553	4257	5493	2030
Percent of leaves rusted	63.	32.3	31.2	86.7
No of spots per rusted leaf	4.8	2.5	2.9	17.5
Percent leaves fallen before Oct. 4	35.9	26.7	22.6	72.6

It should be noted that this table shows the total leaf fall between July 6th and October 4th.

Turning now to the fruit we would refer first to Plate V and Plate VIII as indicating in a general way the fact that a severe rust infection greatly reduces the size of the fruit. In October 1914, twenty-eight trees were carefully selected from which to secure data. The apples were sorted as to grades, firsts being about 2½" or over, and seconds about 2" to 2½"; and as to the number of rusted and non-rusted fruits in each grade. Tables V to VIII give the detailed results, according to the treatment. The dropped fruits mentioned in these tables are such as were under the tree at picking time.

Table V.—*Number and grade of fruit from eight check trees.*

	Bushels	Number	Percent	Rusted Number	Rusted Percent	Healthy Number	Healthy Percent	
Picked Fruits								Total Firsts 3728 20.0%
Firsts	14¾	2612	25.0	1897	72.7	715	27.3	
Seconds	15¾	3754	36.0	2813	74.7	941	25.3	
Culls	11	4020	39.0	3050	75.9	970	24.1	Total Seconds 6059 32.5%
Total picked	41½	10386		7760	74.9	2626	25.1	
Dropped Fruits								
Firsts		1116	13.7	730	65.5	386	34.5	
Seconds		2305	28.0	1538	66.8	767	33.3	Total Culls 8835 47.5%
Culls		4815	58.3	3407	70.8	1408	29.2	
Total drops		8236		5675	68.8	2561	31.2	
Grand total		18622		13435	72.2	5187	27.8	Drops, 44.1%

Average number of apples per tree, 2328.

Table VI.—*Number and grade of fruit from six trees sprayed with lime-sulphur.*

	Bushels	Number	Percent	Rusted		Healthy		
				Number	Percent	Number	Percent	Total Firsts 6676 45.3%
Picked Fruits								
Firsts	35	4904	57.5	1699	34.5	3205	65.5	
Seconds	7	1652	19.4	672	40.7	980	59.3	
Culls	5	1944	23.2	809	41.6	1135	58.4	
Total picked	47	8500		3180	37.4	5320	62.6	Total Seconds 3396 23.1%
Dropped Fruits								
Firsts		1772	28.5	632	35.7	1140	64.3	
Seconds		1744	28.0	704	40.4	1040	59.6	
Culls		2712	43.5	1086	40.0	1626	60.0	Total Culls 4656 31.6%
Total drops		6228		2422	38.9	3806	61.1	
Grand total		14728		5602	38.1	9126	61.9	Drops, 42.4%

Average number of apples per tree, 2455.

Table VII.—*Number and grade of fruit from eight trees sprayed with Bordeaux mixture.*

	Bushels	Number	Percent	Rusted		Healthy		
				Number	Percent	Number	Percent	Total Firsts 8435 38.5%
Picked Fruits								
Firsts	39¼	6323	44.0	3044	48.1	3279	51.9	
Seconds	17¾	4277	29.7	2201	51.5	2076	48.5	
Culls	10¼	3805	26.3	1924	50.7	1881	49.3	
Total picked	67¼	14405		7169	49.6	7236	50.4	Total Seconds 6795 30.9%
Dropped Fruits								
Firsts		2112	27.9	1065	50.3	1047	49.7	
Seconds		2518	33.4	1252	49.5	1266	50.5	
Culls		2921	38.7	1484	50.8	1437	49.2	Total Culls 6726 30.6%
Total drops		7551		3801	50.3	3750	49.7	
Grand total		21956		10970	50.0	10986	50.0	Drops, 34.5%

Average number of apples per tree, 2744.

TABLE VIII.—*Number and grade of fruit from six trees sprayed with atomic sulphur.*

	Bushels	Number	Percent	Rusted		Healthy		
				Number	Percent	Number	Percent	Total Firsts 5589 32.7%
PICKED FRUITS								
Firsts	27¾	4401	37.6	2114	47.9	2287	52.1	
Seconds	17	3652	31.2	2049	56.0	1603	44.0	
Culls	10	3657	31.2	1952	53.3	1705	46.7	
Total picked	54¾	11710		6115	52.2	5595	47.8	Total Seconds 5604 32.8%
DROPPED FRUITS								
Firsts		1188	22.1	583	49.0	605	51.0	
Seconds		1952	36.2	1001	51.3	951	48.7	
Culls		2246	41.7	1263	56.3	983	43.7	Total Culls 5903 34.5%
Total drops		5386		2847	52.8	2539	47.2	
Grand total		17096		8962	52.4	8134	47.6	Drops, 31.5%

Average number of apples per tree, 2849.

It will be noted that there does not appear to be any greater number of rusted fruits among the drops than among those picked. Evidently the rust infected fruit does not show any greater tendency to drop than the other fruit during the latter part of the season. It would be interesting to know whether or not the proportion is the same for rusted fruit drops of the early season, but our records do not cover this point.

The differences in grade of fruit for the various treatments are quite apparent. It must be remembered, however, when we consider this point that the amount of leaf infection may be a prominent factor in the size of fruit. We believe that leaf infection is a far more important factor than fruit infection in determining fruit size.

The fruit data is given in condensed form below:

TABLE IX.—*Summary of rust effect on fruit.*

	TREATMENT			
	Atomic sulphur	Bordeaux	Lime-sulphur	Check
No. fruits counted	17096	21956	14728	18622
Percent fruits rusted	52.4	50.0	42.4	72.2
Percent picked firsts	32.7	38.5	45.3	20.0
Percent picked seconds	32.8	30.9	23.1	32.5
Percent picked culls	34.5	30.6	31.6	47.5
No. of trees	6	8	6	8
Average number of fruits per tree	2849	2744	2455	2328

Some of the evident physiological effects of apple rust infections are premature loss of foliage, under-development of fruit, and in severe cases a great loss of vitality on the part of the tree as indicated by small size, failure to develop fruit buds, etc.

PHYSIOLOGICAL EFFECT OF RUST ON THE CEDAR TREE.

Some of the effects of this fungus upon the cedar tree, *Juniperus virginiana*, have been observed in connection with our work on apple rust, and it may not be out of place to briefly mention them at this time. The production of cedar rust galls of varying size and form is too well known to need further mention. (Plate III, fig. 5.)

A cedar tree which is very heavily infected with rust gives evidence of injury by less vigorous growth. This is especially apparent if the tree has been thus infected on two or more successive years. In particularly severe cases the death of portions of a cedar tree may result.

The apparent immunity of certain cedar trees has been frequently commented upon, and various theories have been advanced to account for this condition. In sections where the rust is destructive, it is quite common to see cedar trees with few or no galls, while other trees within a few feet are actually loaded down with them. Close observation of these "immune" cedar trees has led up to believe that such immunity as they may possess is often a direct result of previous heavy infections. Infection by *Gymnosporangium Juniperi-virginianae* apparently takes place only in young growth. If the tree has been severely diseased with this rust for two or more successive seasons its growth is greatly inhibited, and the opportunity for infection would be proportionately reduced. The two-year life cycle of the fungus must be borne in mind when considering this possibility, as an infection taking place in 1913 does not become apparent until 1914.

A noticeable variation in rate and period of growth has also been observed among cedar trees which were some distance from any apple orchards. It may be that growth factors other than those resulting from rust infection have some bearing upon this matter. We do not have any exact records to prove or disprove this theory, but it is a matter worthy of careful attention.

PLATE VIII.

Fig. 1—Eighteen typical apples from sprayed portion of York Imperial tree, treated May 6, at left. Same number of typical fruits from an unsprayed York Imperial tree, at right. Experiments conducted in 1912.

Fig. 2—Marketable fruit from sprayed portion of York Imperial tree, sprayed May 6, at left. Total fruit from controlled portion of same tree, at right. Experiments conducted in 1912.

Fig. 3—A row of roadside cedars and an apple tree in bloom. Note apple tree is situated in row along with cedars.

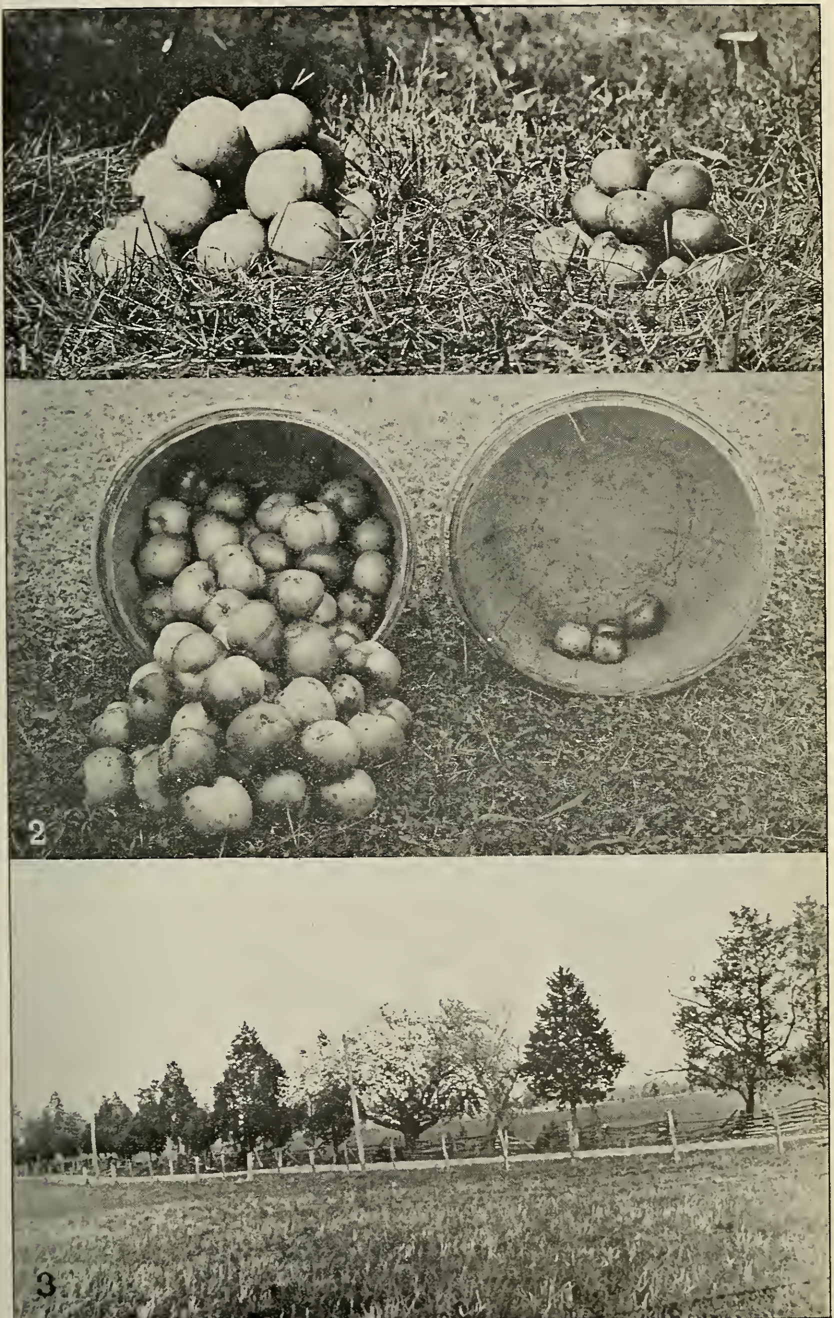
Professor H. H. Whetzell of Cornell University advises us that he has observed a specific case of this apparent immunity in cedars. He has kindly granted up permission to use the following statement.*

"During my senior year in Wabash College I made some studies of the *Gymnosporangium macropus* which occurs very abundantly on cedars and apple trees about Crawfordsville, Indiana. I observed that certain cedar trees were very badly infected, being loaded with galls, large and small, on all their twigs and branches. Other trees standing near were almost or quite free from any infection. A couple of years later I returned to Crawfordsville for a visit and went out again to see the cedar trees from which I had, during my senior year, gotten such large quantities of galls. To my astonishment they were practically free from infection, while others nearby that had borne no galls before were now badly covered with them. What the explanation of this phenomenon is I do not know. It occurred to me, however, that a serious infection of the trees one season might have rendered them more or less immune for a time That the infection was on different trees in these two years is certain, as I was very familiar with the different trees with which I had worked."

CONTROL OF RUST BY SPRAYING.

Ever since spraying for orchard diseases became widely adopted there have been occasional attempts to control apple rust by this method. The varying successes of these trials have been mentioned under historical notes.

*This statement is from unpublished records made by Prof. Whetzell, in connection with some of his early work.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The incidents directly responsible for our taking up experiments along this line were a very severe outbreak of the rust in the eastern part of the state in 1910, and a case in which a few trees were kept free from it by means of spraying. These controlled trees were part of a row along one side of a large orchard. The owner had some atomic sulphur on hand and, incidentally applied it to these apple trees to see how effective it would be. It was at once assumed by nearly everyone in that section that this spray would control rust, while others would not. Inquiry failed to locate any other apple trees sprayed on the same date, and a belief was expressed that lime-sulphur, or Bordeaux mixture, would control this disease just as effectively as the atomic sulphur, if it were applied at the right time.

During the season of 1911 the rust was not very severe, but no orchards were seen in which spraying had effectively controlled it.

Field Experiments in 1912. In 1912 experiments were undertaken to determine the possibility and the practicability of controlling apple rust by the use of spray materials. The orchard selected for this work consisted of about 300 York Imperial trees and 300 of Ben Davis and other varieties combined. It was situated about two miles northwest of Inwood and was commonly known as the Tabb orchard. The cedar trees had been largely cleared away on two sides of the orchard, but were fairly numerous in pasture land bordering the other sides. A nearly square block consisting of 19 York Imperial and 19 Ben Davis trees was chosen near one end of the orchard. The trees were so located that one might reasonably expect them to receive uniform infection.

The only sprays applied to them during the season were those used in this work.

The materials tried were Bordeaux mixture (3 lbs. copper sulphate, 5 lbs. lime, 50 gallons water), commercial lime-sulphur (1 gal. to 40 gals. of water) and atomic sulphur (7 lbs. to 50 gals. of water). Each tree was divided into four parts by imaginary vertical planes. A two-cylinder hand pump was used in applying the spray and a pressure of 50 to 75 lbs. was maintained. One portion of the tree was left unsprayed and each of the other portions was treated with one of the above three spray materials. A large rubber blanket was spread over as much of the control portion as it

would cover, while the tree was being sprayed. A large tag was placed on a branch near the center of each of the four portions after spraying, and no tree was sprayed on more than one date.

Two trees, one Ben Davis and one York Imperial, were handled in this manner on April 22, 24, 29, May 4, 6, 8, 10, 13, 15, 18, 20, 22, 27 and 29. Other trees were similarly treated, but using only Bordeaux and lime-sulphur, on April 18, 20 and May 1: while still others received only lime-sulphur and atomic sulphur on April 26 and May 2.

Before the last of May it became evident that the disease was very largely controlled on certain trees. The sprayed portions of the trees treated May 4 and May 6 were especially free from rust. Counts were made early in June to determine the number of diseased and the number of healthy leaves resulting from each treatment. The results secured from trees sprayed April 26 to May 10 are given below:

Table X.—*Rust control on apple foliage in 1912.*

	York Imperial				Ben Davis			
	Control	Bord. mixt.	Lime-sul.	Atomic sul.	Control	Bord. mix.	Lime-sul.	Atomic sul.
April 26								
No. leaves counted	17	....	50	52	43	....	29	35
Percent diseased	60.0	....	66.0	70.0	34.8	....	34.4	42.8
April 29								
No. leaves counted	163	151	137	134	106	137	133	121
Percent diseased	58.9	43.7	46	64.1	38.8	18.9	30.8	33.0
May 1								
No. leaves counted	125	140	139	....	135	139	141	....
Percent diseased	80.6	65.7	51.1	....	50.3	20.0	27.6	....
May 2								
No. leaves counted	135	....	160	110	136	....	149	128
Percent diseased	70.4	....	60.6	50.0	47.1	....	20.8	22.6
May 4								
No. leaves counted	145	156	147	147	130	185	121	158
Percent diseased	86.9	23.7	53.0	35.4	37.7	8.1	16.5	19.6
May 6								
No. leaves counted	126	150	151	143	157	181	121	146
Percent diseased	78.6	22.6	23.8	23.7	34.3	3.9	10.7	23.9
May 8								
No. leaves counted	138	160	145	154	175	127	142	138
Percent diseased	63.7	63.1	75.8	42.9	39.4	29.9	37.3	32.6
May 10								
No. leaves counted	55	56	25	35	39	30	33	49
Percent diseased	82.0	71.4	84.0	80.0	38.5	26.6	42.4	51.1

It will be seen from this table that each of the three spray materials applied May 6th was quite effective in controlling the rust. Trees sprayed May 4th were fairly well protected, while those sprayed May 2nd showed no benefit.

Notes as to the number of rust spots per leaf show that they were greatly reduced on the sprayed portions of the trees treated May 4th and 6th, but actual counts of them were not made.

The only marketable York Imperial apples in this orchard were secured from the tree sprayed May 6th. Unfortunately, there was little fruit on either the Bordeaux or control portion of this tree.

It was generally stated among the orchard men that the York Imperial fruit was not apt to be attacked to a very great extent. Counts of 600 apples taken from several unsprayed York Imperial trees showed an average of 85% of the fruit rusted, while there were practically no rusted fruits on the sprayed portions of the tree treated May 6th. A comparatively small number of these fruits were deformed by the disease and this was what had evidently led to the belief that only a small number were infected.

The results secured for this season would indicate that there was a very limited period of time when spraying for control of rust might be successfully undertaken. It should also be noted that the trees were in bloom from about May 2nd to May 5th of this year. Beach (1900) found that spraying in bloom caused a very pronounced decrease in the amount of fruit set. The same thing may have been true of the trees used in these experiments, but they all carried a heavy crop of fruit.

Field Experiments in 1913. The Frank Mish orchard and George M. Bowers' orchard at Inwood were selected for this work. The Mish orchard consisted of about 100 York Imperial, 100 Ben Davis and 200 pear trees, while the Bowers orchard contained about 225 York Imperial trees. The trees in the Mish orchard were 11 years old while those in the Bowers orchard were 12 to 14 years old. A great many cedars had been cut in the vicinity of these orchards, but enough remained to give a very heavy rust infection under favorable conditions.

The spray outfit used was Gould's Monarch hand pump mounted in a light wagon. The materials tested were 32° B. lime-sulphur, (1 to 40); Bordeaux mixture, (3 lbs. copper sulphate and 5 lbs lime to 50 gals. water); and atomic sulphur, (7 lbs. to 50 gals. water).

The schedule of spray applications made in these two orchards is given below:

TABLE XI.—*Spraying dates in 1913 experiments.*

BOWERS ORCHARD.

Date	4-16	4-17	4-18	4-22	4-23	4-24	4-25	4-26	4-28	4-29	4-30
Lime-sulphur	x	x	x	x	x	x	x	x	x	x	x
Atomic sulphur	x	x	x	x	x	x	x	x	x	x	x
Bordeaux	x	x	x	x	x	x	x	x	x	x	x

Date	5-1	5-2	5-3	5-5	5-6	5-8	5-12	5-15	5-19	5-22	5-26
Lime-sulphur	x	x	x	x	x	x	x	x	x	x	x
Atomic sulphur	x	x	x	x	x	x	x	x	x	x	x
Bordeaux	x	x	x	x	x	x	x	x	x	x	x

MISH ORCHARD

Date	4-16	4-17	4-18	4-21	4-22	4-23	4-24	4-25	4-29	4-30	5-1
Lime-sulphur	x	x	x	x	x		x	x	x	x	x
Atomic sulphur	x	x	x			x	x	x		x	x
Bordeaux	x	x	x	x		x	x	x	x	x	x

Date	5-2	5-3	5-5	5-8	5-14
Lime-sulphur	x	x	x	x	x
Atomic sulphur		x	x	x	x
Bordeaux		x	x		x

Three trees were included in the test for each material, on every date, in the Bowers orchard; and two trees (one York Imperial and one Ben Davis) for each material on every date in the Mish orchard. There was a fair amount of bloom in the Bowers orchard and scattering bloom on the Yorks in the Mish orchard. The Ben Davis trees in the latter orchard had very fair bloom, but late frosts destroyed practically all of the fruit in both orchards. In Table XII is given the number and distribution of rust spots on foliage in the Bowers orchards.* The twigs used in making these counts were carefully selected to show average conditions and were taken from different sides of the trees.

*In some cases it will be noted that there are over 300 rust spots per leaf. The spot counts up to 200 per leaf are believed to be very accurate, but there is probably an error of 5% in any count which runs above 300 spots per leaf.

Table XII.—*Number and distribution of rust spots on York Imperial apple foliage in Bowers orchard during 1913.*

Tree Number, 176 — Treatment, Lime-sulphur — Date of Treatment, May 15, 1913

		1	2	3	4	5	6	7	8	9	10	11	12
Spur number		1	2	3	4	5	6	7	8	9	10	11	12
No. of leaves		13	12	9	6	7	8	10	7	7	7	7	5
No. of rust spots		15	3	12	1	0	0	0	2	2	0	0	0
Distribution of rust spots	Leaf No. 1	0	0	3	0	0	0	0	0	1	0	0	0
	Leaf No. 2	1	0	0	0	0	0	0	0	1	0	0	0
	Leaf No. 3	0	2	2	1	0	0	0	1	0	0	0	0
	Leaf No. 4	1	0	1	0	0	0	0	0	0	0	0	0
	Leaf No. 5	1	1	0	0	0	0	0	0	0	0	0	0
	Leaf No. 6	0	0	0	0	0	0	0	0	0	0	0	
	Leaf No. 7	0	0	0		0	0	0	1	0	0	0	
	Leaf No. 8	0	0	6			0	0					
	Leaf No. 9	0	0	0				0					
	Leaf No. 10	5	0					0					
	Leaf No. 11	7	0										
	Leaf No. 12	0	0										
	Leaf No. 13	0											

Total number leaves........ 98
Total rusted leaves........ 16
Percent rusted leaves........ 16.3
Total rust spots........ 35
Spots per rusted leaf........ 2.2

Tree Number, Check — Treatment, None

		1	2	3	4	5	6	7	8	9	10	11	12
Spur number		1	2	3	4	5	6	7	8	9	10	11	12
No. of leaves		8	11	5	11	13	5	8	7	9	10	5	9
No. of rust spots		296	792	139	511	886	478	345	603	347	171	371	373
Distribution of rust spots	Leaf No. 1	0	0	0	0	0	0	0	0	0	0	0	0
	Leaf No. 2	0	0	0	0	0	0	0	1	0	0	1	0
	Leaf No. 3	0	0	0	0	0	20	0	7	0	0	30	0
	Leaf No. 4	0	0	42	0	1	124	1	171	0	0	206	0
	Leaf No. 5	1	0	97	0	0	334	26	303	1	0	134	0
	Leaf No. 6	13	4		46	0		207	121	64	0		2
	Leaf No. 7	155	48		86	72		103	0	215	0		16
	Leaf No. 8	127	333		297	229		8		67	25		252
	Leaf No. 9		331		69	357				0	276		103
	Leaf No. 10		76		13	207					170		
	Leaf No. 11		0		0	20							
	Leaf No. 12					0							
	Leaf No. 13					0							

Total number leaves........ 101
Total rusted leaves........ 50
Percent rusted leaves........ 50.0
Total rust spots........ 5312
Spots per rusted leaf........ 112

The general effectiveness of these sprays for controlling the rust in the Bowers orchard is shown in Table XIII. The rust infection was very unevenly distributed through this orchard as a result of there being some large cedars within two or three rods of it, along one side. The first check tree given in this table was quite near some of these cedars.

Table XIII.—*Rust control on York Imperial apple foliage in Bowers orchard during 1913.*

No.	Date	Treatment	Total	Rusted		Healthy		Spots per rusted leaf
				Number	Percent	Number	Percent	
128	5-3	Lime-sulphur	100	42	42.0	58	58.0	80.5
132	5-3	Bordeaux	75	29	38.7	46	61.3	32.7
129	5-3	Atomic sulphur	100	30	30.0	70	70.0	32.3
161	5-8	Lime-sulphur	87	15	17.3	72	82.7	13.1
163	5-8	Bordeaux	100	30	30.0	70	70.0	9.9
156	5-8	Atomic sulphur	98	29	29.5	69	70.5	16.8
168	5-12	Lime-sulphur	91	12	13.2	79	86.8	5.3
167	5-12	Bordeaux	111	28	25.2	83	74.9	20.3
171	5-12	Atomic sulphur	109	21	19.3	88	80.7	9.1
176	5-15	Lime-sulphur	98	16	16.3	82	83.7	2.2
181	5-15	Bordeaux	116	28	24.1	88	75.9	2.9
178	5-15	Atomic sulphur	112	24	21.4	88	78.6	10.1
		Check	101	49	48.6	52	51.4	127
		Check	104	48	46.2	56	53.8	62

Our results for the season 1913 would indicate that one spray application seven days previous to the date of infection may be fairly effective in controlling apple rust on the foliage, while an application twelve days previous was not of much value. The lime sulphur gave the best control, and Bordeaux mixture next.

The trees were in bloom April 23rd to April 27th, 1913, but the late frosts, previously mentioned, prevented securing any data as to control of rust on fruit, or effect on fruit production, of applications at blooming time.

Field Experiments in 1914. An orchard in Jefferson County, owned by Dr. A. P. Thompson, was secured for our work in 1914. This orchard consisted of about 300 York Imperial trees, thirteen years of age, situated along the side and top of a ridge. The trees were in good condition although they had suffered severely from rust during some of the past seasons. A large number of cedars had been cut along one side of the orchard, but there were still many of them on three sides, within ten to forty rods of it. The orchard was very free from diseases, aside from apple rust.

The general plan of the experiment may be divided into two parts. First, to apply each spray material to a few previously unsprayed trees on each day, so far as practicable, in order to determine the effectiveness of one spray application given at any specified time during the spring. The second aim was to learn whether several applications at two weeks, one week, or half week intervals would be effective in controlling the rust.

The orchard was carefully plotted and the trees tagged and numbered consecutively. The spray materials tested were atomic sulphur (7 lbs to 50 gals.); Bordeaux mixture (3 lbs. copper sulphate, and 5 lbs. lime to 50 gals.); and 35° B. home made concentrated lime-sulphur (1 to 40). The sprays were applied with a Hardie Junior power outfit, which gave very satisfactory service. A pressure of about 200 pounds was maintained. The tank, hose, and rod were washed out before placing in the tank a spray material different from the one last used.

The trees which were to be sprayed on successive dates were divided into six blocks and the trees in each block were clearly indicated by a white letter painted on the trunk of the trees. The spray to be used on any tree was indicated by one, two, or three white bands painted around the trunk. Having them marked this way saved considerable time for the man who was spraying and greatly reduced the chance of his making a mistake.

Rainy weather, and unavoidable difficulties of one kind or another rendered it impossible to carry out the full spraying schedule on the exact dates planned. The applications on these blocks were made as follows:

*TABLE XIV.—*Spray schedule for successive applications in 1914.*

	No. Trees Bord.	No. Trees L. S.	No. Trees At. S.	Date Sprayed
Block A	3	5	3	Apr. 28, May 1, (L.S.), 2 (Bord. & At.S.), 4, 7, 11.
Block B	3	4	3	Apr. 28, May 1, (L.S.), 2 (Bord. & At.S.), 4, 7, 11.
Block C	Unsprayed trees among sprayed blocks.			
Block D	3	4	3	May 1, (L.S.), 2 (Bord. & At.S.), 4, 7, 11, 14.
Block E	3	4	3	April 28, May 4, 11.
Block F	4	4	3	April 28, May 4, 11, 18, 25 (Bord.), May 26 (L.S. & At.S.)
Block G	3	5	3	April 28, May 4, 11, 18.

*L. S. stands for lime-sulphur, Bord. for Bordeaux, and At. S. for atomic sulphur. Unless otherwise stated, all sprays were applied. The spraying on block A was discontinued after May 11th, by mistake, so that blocks A and B are duplicates.

If further work is conducted along this line the spraying schedule might well be planned so that there would be no

one date when all the blocks would be treated. It so happened that the only serious rust infection of the 1914 season occurred May 5th, and all of the blocks had been sprayed on the previous day. As a result, we found no more difference between the blocks than would be accounted for by ordinary variation.

The method used in securing data from foliage will be briefly outlined. Three trees in each block were selected for **check twig** data. One of these trees was sprayed with lime-sulphur, one with Bordeaux, and one with atomic sulphur; but just before applying the spray four exposed twigs on different sides of the tree were tagged and covered with large paper sacks. As soon as the tree had been sprayed these sacks were removed. While they received none of the spray directly, it was found that they did receive an appreciable amount due to the bending down of branches higher up, combined with the action of the rain and wind. The amount of protection which such twigs secured in that way will be indicated in the next table. These four twigs were covered each time that the tree was sprayed. Four other twigs, comparable in size and exposure, were chosen on the same trees to give data as to the effectiveness of the spray. On all other sprayed trees four sprayed twigs on four sides of the tree were selected for counting. The twigs on a tree were numbered from 1 to 4 or from 1 to 8, according to whether or not there were any check twigs on it. On all check trees four twigs were taken, under similar conditions as regards size and exposure. A separate note book page was used for the data from each twig. The leaves on a twig were not counted as a whole, but the number from each bud was put down separately. This method was found very accurate and required little more time than the other. The number of spots was actually counted on each rusted leaf for at least the terminal growth of each of the eight twigs on trees which had check twigs, as shown on page 50. Similar spot counts were made on four twigs on each of ten check trees. The first two leaves to unfold, sometimes called the bud leaves, were removed before the first count was made.

As previously stated, these blocks show practically no difference in the effectiveness of the treatments as regards dates of application. It has therefore seemed advisable to omit the lengthy tabulations which would be required to show this, and to present the data from the standpoint of materials only. Table XV gives the number and distribution of rust spots on the foliage of four trees, selected to give as nearly typical and comparable results as seem possible.

TABLE XV.—*Number and distribution of rust spots on York Imperial apple foliage in Dr. A. P. Thompson's orchards during 1914.*

	Tree Number, 320 — Treatment, Atomic Sulphur, Block E															
	Check twigs								Sprayed twigs							
Spur number	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
No. of leaves....	9	8	11	10	8	5	7	7	12	8	8	11	13	7	8	7
No. of rust spots	49	53	110	47	53	88	21	28	46	24	17	38	20	13	27	9
Distribution of rust spots: Leaf No. 1	2	10	12	18	31	25	1	3	10	0	2	0	0	0	1	0
Leaf No. 2	6	18	24	8	17	19	4	9	6	11	2	2	2	1	0	0
Leaf No. 3	13	9	15	3	1	21	3	3	9	6	2	5	7	3	7	4
Leaf No. 4	17	8	14	12	2	22	13	7	5	2	4	17	3	3	2	2
Leaf No. 5	10	8	38	5	0	1	0	6	3	2	7	0	4	6	5	2
Leaf No. 6	0	0	0	0	0		0	0	1	3	0	0	2	0	2	1
Leaf No. 7	1	0	1	0	1		0	0	0	0	0	0	0	0	5	0
Leaf No. 8	0	0	0	0	1				0	0	0	0	0		5	
Leaf No. 9	0		0	0					0			0	0			
Leaf No. 10			1	1					6			6	0			
Leaf No. 11			5						6			8	0			
Leaf No. 12									0				2			
Leaf No. 13													0			
	Total number leaves.... 65 Total rusted leaves...... 45 Percent rusted leaves.. 69.0 Total rust spots............449 Spots per rusted leaf.... 10								Total number leaves.... 74 Total rusted leaves...... 44 Percent rusted leaves.. 59.0 Total rust spots............194 Spots per rusted leaf.. 4.4							

	Tree Number, 319 — Treatment, Bordeaux, Block F															
	Check twigs								Sprayed twigs							
Spur number	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
No. of leaves....	5	9	4	6	9	5	10	7	10	9	4	8	7	11	8	
No. of rust spots	0	81	0	12	67	15	37	29	35	10	6	11	1	12	10	
Distribution of rust spots: Leaf No. 1	0	8	0	4	13	5	7	4	0	0	1	2	0	0	1	
Leaf No. 2	0	15	0	1	19	6	8	14	1	3	3	0	0	0	2	
Leaf No. 3	0	14	0	6	6	3	4	9	6	0	0	6	0	2	3	
Leaf No. 4	0	40	0	1	14	1	14	1	0	2	2	2	0	0	4	
Leaf No. 5	0	3		0	8	0	0	1	1	3		0	0	6	0	
Leaf No. 6		0		0	4		0	0	0	0		1	0	2	0	
Leaf No. 7		0			3		0	0	0	0		0	1	0	0	
Leaf No. 8		0			0		0		0	0		0		0	0	
Leaf No. 9		1			0		4		12	2			0			
Leaf No. 10							0		15					1		
Leaf No. 11														1		
Leaf No. 12																
Leaf No. 13																
	Total number leaves.... 55 Total rusted leaves...... 31 Percent rusted leaves.. 56.5 Total rust spots..........241 Spots per rusted leaf.. 8								Total number leaves.... 57 Total rusted leaves...... 26 Percent rusted leaves.. 45.5 Total rust spots............ 85 Spots per rusted leaf.. 3.2							

Tree Number, 370

Treatment, Lime-sulphur, Block D.

Check twigs

Spur number	1	2	3	4	5	6	7	8
No. of leaves	7	6	5	5	7	5	9	5
No. of rust spots	40	74	227	136	52	109	252	157
Distribution of rust spots: Leaf No. 1	6	30	44	64	1	50	34	2
Leaf No. 2	16	8	66	62	15	26	96	67
Leaf No. 3	9	27	105	10	30	30	61	63
Leaf No. 4	7	5	12	0	3	2	46	20
Leaf No. 5	2	4	0	0	2	1	10	5
Leaf No. 6	0	0			1		0	
Leaf No. 7	0				0		0	
Leaf No. 8							3	
Leaf No. 9							2	
Leaf No. 10								

Total number leaves.. 49
Total rusted leaves........40
Percent rusted leaves 81.6
Total rust spots.........1047
Spots per rusted leaf.. 20

Sprayed twigs

Spur number	1	2	3	4	5	6	7	8
No. of leaves	4	6	10	8	3	5	6	7
No. of rust spots	11	10	4	0	3	1	1	1
Distribution of rust spots: Leaf No. 1	7	6	1	0	0	0	0	0
Leaf No. 2	2	2	0	0	2	1	0	0
Leaf No. 3	2	1	1	0	1	0	0	0
Leaf No. 4	0	0	0	0		0	1	1
Leaf No. 5		0	0	0		0	0	0
Leaf No. 6		1	2	0			0	0
Leaf No. 7			0	0				0
Leaf No. 8			0	0				
Leaf No. 9			0					
Leaf No. 10			0					

Total number leaves.. 49
Total rusted leaves.... 12
Percent rusted leaves 24.5
Total rust spots......... 67
Spots per rusted leaf.. 5.5

Tree Number 251

Check

Spur number	1	2	3	4	5	6	7	8
No. of leaves	7	6	8	6	5	4	8	6
No. of rust spots	132	135	224	200	137	126	142	100
Distribution of rust spots: Leaf No. 1	25	26	17	30	88	47	27	33
Leaf No. 2	23	44	37	91	19	43	51	35
Leaf No. 3	39	21	56	43	27	33	36	19
Leaf No. 4	30	20	47	33	3	3	24	10
Leaf No. 5	14	22	50	3	0		4	3
Leaf No. 6	1	2	17	0			0	0
Leaf No. 7	0		0				0	
Leaf No. 8			0				0	
Leaf No. 9								
Leaf No. 10								

Total number leaves.... 50
Total rusted leaves...... 41
Percent rusted leaves.. 82
Total rust spots...........1196
Spots per rusted leaf.... 29.8

Tree Number 369

Check

Spur number	1	2	3	4	5	6	7	8
No. of leaves	9	4	8	8	9	5	7	6
No. of rust spots	141	87	198	157	146	168	305	219
Distribution of rust spots: Leaf No. 1	49	17	48	23	41	92	30	92
Leaf No. 2	53	56	47	44	33	43	82	36
Leaf No. 3	35	13	55	37	37	24	34	58
Leaf No. 4	4	1	24	28	28	5	72	18
Leaf No. 5	0		23	21	5	0	44	13
Leaf No. 6	0		1	4	0		11	2
Leaf No. 7	0		0	0	0		2	
Leaf No. 8	0		0	0	0			
Leaf No. 9	0				2			
Leaf No. 10								

Total number leaves.... 56
Total rusted leaves...... 43
Percent rusted leaves.. 77
Total rust spots...........1421
Spots per rusted leaf.... 33

Table XVI shows the total results for each spray material used on the trees which were sprayed on successive dates.

TABLE XVI.—*Summary of rust control on York Imperial apple foliage sprayed on successive dates.*

LEAVES ON SPRAYED TWIGS

Number of trees	Spray	Total leaves	Rusted		Healthy	
			Number	Percent	Number	Percent
23	Lime-sulphur	5493	1780	32.4	3713	67.6
18	Bordeaux	4257	1401	33.0	2856	67.0
18	Atomic sulphur	4543	2856	62.9	1687	37.1
	CHECK TWIGS					
6	Lime-sulphur	1450	1121	77.4	329	22.6
6	Bordeaux	1384	845	61.0	539	39.0
6	Atomic sulphur	1580	1286	81.4	294	18.6
	Unsprayed	2030	1837	90.5	193	9.5

These results, secured from a number of trees and including 1300 to 5000 leaves for each treatment should give a very fair average. The lime-sulphur is evidently best, with Bordeaux a close second. The general effect of the spray on the check twigs of sprayed trees may also be noted. The average of rusted leaves on check trees was over 90% while on the check twigs of sprayed trees it falls as low as 61% in the case of Bordeaux mixture.

There was a heavy crop of apples on nearly every tree in this orchard. Data regarding the control of rust on fruit was therefore secured from a number of trees. The figures in Table XVII include both drops and picked fruit. By the term "drops" we mean, in this case, such fruits as were on the ground under the trees at picking time.

TABLE XVII.—*Summary of rust control on York Imperial apple fruits sprayed on successive dates.*

Treatment	Total fruits	Rusted		Healthy		Number of trees	Average number fruits per tree
		Number	Percent	Number	Percent		
Check	18622	13435	72.2	5187	27.8	8	2328
Lime-sulphur	14728	5602	38.1	9128	61.9	6	2455
Bordeaux	21956	10970	50.0	10986	50.0	8	2744
Atomic sulphur	17096	8962	52.4	8134	47.6	6	2849

Each of the spray materials gave a very pronounced reduction in the percent of rusted fruit, but the lime-sulphur shows up particularly well.

Turning from the trees which received several successive applications of spray, we will take up those which were sprayed but once. The dates and materials used in this part of the work are indicated below.

Table XVIII.—*Spray schedule for single application in 1914.*

Date	Number of trees sprayed		
	Bordeaux	Lime-sulphur	Atomic sulphur
April 28	3	3	3
April 29		3	
May 1		3	
May 2	3		1
May 4	3	3	3
May 5	7	2	
May 6	3	7	7
May 7	3	3	3
May 8		3	
May 9	3		3
May 11	1	1	1
May 12	3	3	3
May 13	3	3	
May 14	3	3	
May 15	3	3	
May 18	3	3	
May 19		3	
May 20	3	3	
May 21	3	3	
May 22	3	3	
May 23	3		
May 25	3	3	
May 26	2	2	
May 28	2	2	

Check twigs were retained on each of the trees used. Since there was no important rust infection after May 5th, counts were made only on trees sprayed previous to that date. Table XIX shows the effectiveness of the treatments.

TABLE XIX.—*Rust control on York Imperial apple foliage as a result of single spray applications in 1914.*

LEAVES ON SPRAYED TWIGS

Tree number	Date	Spray	Total number	Rusted		Healthy	
				Number	Percent	Number	Percent
43	April 28	Lime-sulphur	215	183	85.0	34	15.0
44	April 28	Atomic sulphur	306	229	75.0	77	25.0
45	April 28	Bordeaux	251	151	60.0	100	40.0
242	April 29	Lime-sulphur	273	156	27.0	118	43.0
204	May 1	Lime-sulphur	289	174	60.0	115	40.0
191	May 1	Bordeaux	260	144	55.4	106	44.6
219	May 1	Atomic sulphur	232	166	71.0	66	29.0
249	May 2	Lime-sulphur	312	145	46.5	167	53.5
221	May 2	Bordeaux	222	93	42.0	132	58.0
4	May 4	Lime-sulphur	334	88	26.5	246	73.5
5	May 4	Atomic sulphur	279	132	48.0	147	52.0
7	May 4	Bordeaux	348	63	18.0	285	82.0

LEAVES ON CHECKED TWIGS

Tree number	Date	Spray	Total number	Rusted Number	Rusted Percent	Healthy Number	Healthy Percent
42		Check	186	161	87.0	25	13.0
43	April 28	Lime-sulphur	201	147	73.0	54	27.0
44	April 28	Atomic sulphur	227	174	76.5	53	23.5
45	April 28	Bordeaux	325	215	66.0	110	34.0
242	April 29	Lime-sulphur	230	185	81.0	45	19.0
204	May 1	Lime-sulphur	230	202	88.0	28	12.0
191	May 1	Bordeaux	261	220	84.1	41	15.8
219	May 1	Atomic sulphur	194	163	84.0	31	16.0
249	May 2	Lime-sulphur	147	127	86.4	20	13.6
221	May 2	Bordeaux	168	126	75.0	42	25.0
4	May 4	Lime-sulphur	247	176	72.0	71	28.0
5	May 4	Atomic sulphur	247	151	62.0	96	38.0
7	May 4	Bordeaux	293	147	50.0	146	50.0
223		Check	162	153	95.0	9	5.0

The results of these trials would indicate that a spray application one week previous to infection is ineffective for control of rust, while the same material applied one day previously is very effective and applied three days previously is fairly effective.

The data for 1912 indicated practically the same thing. The date of infection in 1914 was almost the same as in 1912 and the date of blooming for the trees in 1912 was about May 2-5, while in 1914 it was May 1-5. The blossom buds were just showing good color on April 27th, and the so-called cluster bud spray was being applied at that time in a nearby orchard. A large portion of the central blossom buds opened

on May 1st. May 4th, practically every blossom had opened and during that day a very few petals fell from the earlier blossoms. It was impossible to spray until about noon, on May 5th, and applications made at that time showed no control of rust. The only time when spray could have been effectively applied for the control of apple rust in 1914 was when the trees were in bloom.

The conclusion which we would draw from these spraying experiments is that the disease is readily controlled by the common spray mixtures such as lime-sulphur, Bordeaux mixture, and atomic sulphur; that lime-sulphur is most efficent; and that a successful spray schedule for rust control must take into account the rate of growth of the young leaves. We do not believe that the apple rust disease can be consistently and regularly controlled by the use of less than six or seven applications during the spring. Such a spraying schedule would be about as follows:

First Application—When blossom buds are showing good color. (Arsenate might be included.)

Second Application—Within one or two days after first blossoms open. (No arsenicals.)

Third Application—As soon as ½ to ⅔ of bloom has dropped. (No arsenicals.)

Fourth Application—3 to 4 days after third. (Include arsenate.)

Fifth Application—5 to 6 days after fourth. (No arsenicals.)

Sixth Application—5 to 6 days after fifth. (No arsenicals.)

Seventh Application—6 to 7 days after sixth. (No arsenicals.)

The second, third, fourth, fifth, and sixth are believed to be the most important. The spraying must, of course, be thoroughly done, and the impracticability of carrying out such a spray schedule in a large orchard is self evident.

A glance at the last column in Table XVII will show that there were more fruits matured upon the trees sprayed May 4th, in full bloom, than upon the check trees. Many young fruits may have been killed, but the trees still needed thinning. From our experiments thus far, we would not hesitate to recommend that York Imperial apple trees, showing a good amount of bloom, should receive one spray appli-

PLATE IX.

Fig. 1—Cedar trees scattered in with other growth at Falling Waters, W. Va.

Fig. 2—Instrument shelter for hygrothermograph, showing exposure.

Fig. 3—Cedar trees in pasture field near Inwood, W. Va.

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cation of lime-sulphur without arsenical poison while they are in bloom, provided the apple rust is prevalent and destructive in that section.

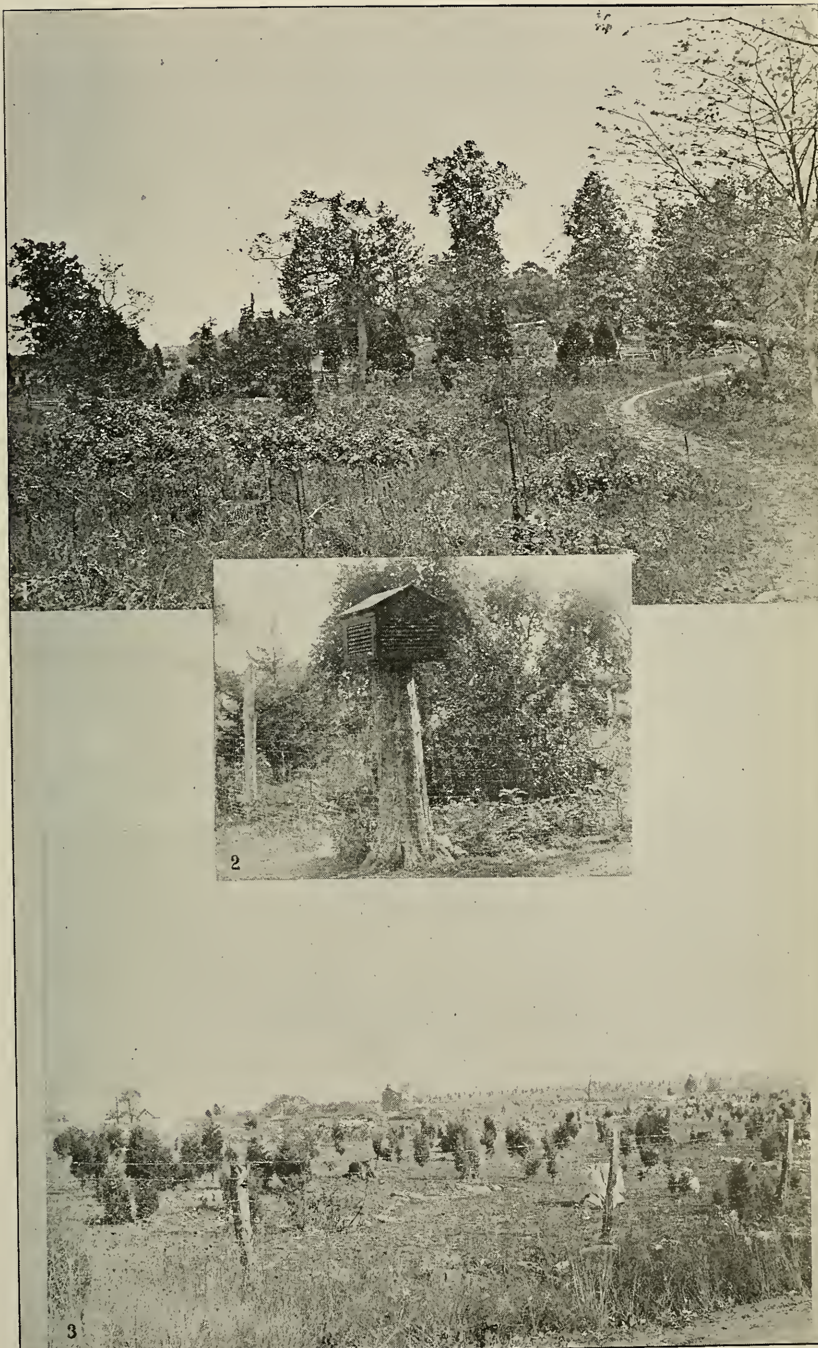
So far as we have been able to learn, there is no evidence that the lime-sulphur spray would be injurious to bees visiting the blossoms after this spray has been applied.

DESTRUCTION OF RED CEDARS AS A METHOD OF CONTROL.

The destruction of the red cedar has been quite universally recommended as the best and most practical method of controlling apple rust. Although this method of control is so generally accepted we find only one reference to a careful experiment for determining its efficiency. Jones (1893, p. 83) as quoted on page 6, secured some definite evidence regarding this point.

Reed (1914, p. 23) gives reports from orchard men as to the effectiveness of cutting out cedars, but details as to distances, area, etc. are not mentioned.

The value of the cedars must be taken into consideration when dealing with a problem of this kind. The red cedar, *Juniperus virginianac* is of very little commercial importance in West Virginia. It occurs quite commonly throughout the state and is abundant in some of the principal apple growing sections. Most of the growth is of no value because of its inferior, bushy development. There are many fields which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3

should be cleared of these scrub cedars because of the increased pasture value which would result. (Plate IX, fig. 3.) The larger trees find use as fence posts and telephone poles, but comparatively few are valuable for sawed lumber, and it is said that only the red, heart wood is good for fence posts. The sentimental value which may be attached to cedars is often a factor of great importance, and is far more difficult to deal with than a mere commercial value. There are very few places where the value of an orchard would not greatly outweigh the value of all the red cedar trees to be found within such range that they would be likely to produce serious rust infection.

The very destructive apple rust infection of 1912 brought this disease to a conspicuous place in the list of apple enemies, and during the year 1913 the State Crop Pest Commission took action in regard to the destruction of red cedars in certain sections of West Virginia. The state law, governing such matters, granted this commission authority to make the necessary rules and regulations likely to be required for any case of this kind.* Rules relative to the destruction of red cedars, harboring this disease, were issued in February, 1913, and the agents of the commission began active work in November, 1913.

Of course every reasonable effort was used to have the cedars removed without a direct application of the processes of law. Difficulties were met with and overcome, and much valuable work has been accomplished along this line.†

The cost of cutting out cedars is often given as an argument against the general application of this method. Mr. S. L. Dodd, Jr.‡ has secured some valuable data for us along this line, showing the actual cost of such work. This cedar destruction was carried on in Berkeley County, West Virginia. The facts are given in some detail, since it is essential to know the conditions under which the work was done. Mr. Dodd's report is as follows:

"The first locality where much work was done is at Tablers Station on the lands adjoining the orchards

*Copies of the state law, and the special rules of the State Crop Pest Commission may be secured from the State Entomologist, Morgantown, W. Va.

†Further details in regard to this work are given by W. E. Rumsey in the First Biennial Report of the State Crop Pest Commission.

‡S. L. Dodd, Jr. is the State Crop Pest Commission inspector for Berkeley County. He is well acquainted with conditions in that section, and has had personal charge of much of the cutting out work.

of C. C. Borum, J. W. Stewart, and Lord & Harrison. At this point approximately 350 acres have been cleared of cedars and there remain about 225 acres to clear yet. Of the 350 acres cleared, about 100 acres were in wood lot where the cedars were overrun with grape vines, and the underbrush was heavy, thus making the cutting more expensive and much harder. The other 250 acres were cleared much cheaper as the trees were for the most part located in fence rows and on rock breaks in the fields. These cedars were nearly all from 15 to 25 feet in height although there may have been 20% which were smaller (from two to ten feet). In the wood lot the trees were very thick, while in the fence rows they were more scattered. On 250 acres of this land nine men were employed two days, seven of them receiving $1.00 and the other two who were inspectors, $3.00 per day. Eleven men were employed two days clearing another fifty acres. Eight of these men were paid at the rate of $1.00 per day, two at $3.00 and one at $2.00. Twenty-five more acres required ten men for two days, seven men at $1.00 per day, two at $3.00 and one at $2.00; while on the remaining twenty-five acres two were employed eight days, one at $3.00 and one at $2.00 per day. This makes a total of $128.00 for the 350 acres. On the 250 acres in fence rows and breaks the cedars were trimmed up and the brush piled ready to be burned.

"The second place which should be mentioned is at Darkesville on lands adjoining the McDonald orchard. There was some cutting done in this locality by the property owners, but the cost is not obtainable, and that area is not included. There were 200 acres in the place where we did the cutting and the cedars were scattered over the whole of it, in fence rows and on rock breaks. In this case the trees were trimmed up and the brush piled and I think burned. These trees were mostly very large, being from twenty to twenty-five feet in height. A few along the fence row in one field were very small. Six men were employed six days; four of them receiving $1.25, and the other two $3.00 per day. This makes a total of $66.00 to clean up the 200 acres.

"The third place where extensive cutting was done is around the Cherry Hill Orchard Company's place in Falling Waters District. We have cut the cedars on about 200 acres but there are still about 600 acres which should be cleared. On 100 acres of the land cut over last year the cedars were small, being from two to six feet in height, and were scattered over large open fields. On the other 100 acres the trees

PLATE X.

Meteorological instruments, showing equipment and exposure.

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were larger, being from 15 to 20 feet in height, and about half of them were in a wood lot while the rest were in fields and around fence rows.

"On the first 100 acres two men were employed six days, one at three and the other at two dollars. On the last 100 acres two men were employed five days at the same rate of pay as before. In this case we trimmed up the trees and left them in poles. We began cutting again at this place a few days ago and about 5 acres were cleared by one man in one day, at $3.00 per day. A total of $58.00 has been spent in cutting out the cedars from 205 acres at this place.

"The next locality where work was done is in Falling Waters District around the orchards of Mr. George Ryneal, Jr. The cedar trees here were all large, running from twenty to thirty feet in height. Most of them were located on the river cliff, and in with other timber. Owing to the fact that the ground is quite high at this point the spores from these trees would blow over a very large area, making it particularly important to have them removed. Twenty-five acres of this land had the cedars scattered along fence rows and on rock breaks. More than half of the trees have been cut by the owner without any help from the state whatsoever. This man also helped when we were cutting in that neighborhood. There have been about 65 acres cleared of cedars at this point. On the first 25 acres four men were employed ten days and were paid $1.25 per day. On the remaining 40 acres five men were used for six days, four at $1.25, and one at $2.00, making a total of $92.00.

"At Ridgeway we did some cutting around the Clohan orchards which are about a mile from the station. On one farm we cleared out a thicket composed almost entirely of cedars. These trees were very tall and straight and in order to get them cut we had to trim them into poles and pile the brush. This thicket stood about three-fourths of a mile from the Clohan orchard and was on the western side on high ground. As the winds come mostly from this direction it was very important to remove the cedars.

"There are about seven or eight acres in the clearing and it took four men, ten days to complete the job. One of these men received $3.00, another $2.00 and the other two men $1.25 each per day. This makes a total of $75.00 to finish the work at that place.

"The cedars were also destroyed on about 100 acres close around this orchard. The trees here were from fifteen to twenty feet in height and located along the fences. On this there were five men employed for three days. Three received $1.25, one $2.00 and one $3.00 per day, which makes a total of $26.25 in all. In this case we again trimmed up the trees and piled the brush.

"The cedars were also cleared from 15 acres of wood lot. The trees were 10 to 15 feet tall and the largest of them were trimmed up for posts. Six men were employed for one day. Four of them received $1.25 each, one $2.00 and the other $3.00 per day, making a total of $10.00.

"At Parks Gap on Dry Run Pike, around the orchards of J. H. Fishell, S. S. Felker and the Sperows, about 150 acres were cleared. On twenty-five acres of this the trees were small and in the open field at the foot of the mountain. The cedars on the remaining 125 acres were larger and were on the mountain, making it very hard to cut them. One man at $2.00 per day was employed for six days to cut the twenty-five acres. On the other 125 acres four men were employed five days. Two of them were paid $1.25 each, one $3.00 and one $2.00 per day. The last trees were trimmed up and left in poles. They were mostly about fifteen to twenty feet in height. The total cost in this case was $49.50.

"The Pittsburgh Orchards Co. of Hedgesville report cutting the cedars from 21.2 acres at a cost of $19.93. The trees were mostly fifteen to twenty feet tall and varied from

sparse to thickly clustered clumps with many grape vines among them. The time required to do this work was 152½ hours and the average rate of pay per hour was 13c. They say, 'In our experience the cutting of cedars is inexpensive and rapid work, and were the cost increased an hundredfold, it would be insignificant in comparison with the benefit established.'

"This data is as near accurate as I am able to get it, and hope that it will serve your purpose. You will understand that this is the cost of cutting only, and not the cost of marking and the numerous trips in order to get the owners consent to do the cutting.

"There are other places where cutting has been done, but I have no information as to the cost. There are also a great many places where we cut a day or so, but the work is so incomplete that it would be unwise to include it in this report. In many cases we simply got the trees marked but none cut."

Table XX.—*Cost of destroying cedar trees.*

Acres cleared*	Days required	No. men employed	Average rate per day per man	Total cost
250	2	9	$1.44	$ 26.00
50	2	11	1.49	32.00
25	2	10	1.50	30.00
25	8	2	2.50	40.00
200	6	6	1.83	66.00
Picking galls	4	1	2.00	8.00
100	6	2	2.50	30.00
100	5	2	2.50	25.00
5	1	1	3.00	3.00
25	10	4	1.25	50.00
40	6	5	1.40	42.00
7.5	10	4	1.87	75.00
100	3	5	1.75	26.25
25	6	1	2.00	12.00
125	5	4	1.87	37.50
15	1	6	1.67	10.00
21.2	152.5 hrs.		1.30	19.93
1113,7				$532.68

*By the term, "acres cleared," we mean only such land as was actually included in a general cedar growth, such as a grove or wood lot; and, in the case of fence row trees, the immediately adjacent field which they bounded. This is possibly clearer in the previous detailed statements.

The total time required for this work was 311 days and the average rate of pay was $1.71 per day. The average cost per acre was less than 48 cents.

From these figures it would appear that, under average conditions such as exist in Berkeley County of West Virginia,

the actual cost of removing cedar trees for a radius of one mile around an orchard of 600 or more susceptible trees would be about equal to the fruit loss which might be expected to occur in one season as the result of a severe infection of apple rust. In other words, it is quite possible that one season's increased profit resulting from cedar tree destruction will entirely pay for the cost of cleaning up the cedars.

The cutting out which was done during the winters of 1910-11 and 1911-12 undoubtedly saved much of the York Imperial apple crop from complete destruction in at least two large orchards in 1912. In so far as we know, these two orchard are the only ones around which there had been any active and systematic work in cedar tree destruction. Good results have also been secured from the more recent work along this line. Mr. Dodd, in his report, says, "At none of the places mentioned in my report have all the cedars been cut back to one-half mile and in some places they are up against orchard fences.

"In several instances our cedar cutting of last year brought good results, but this was because the cedars happened to be cut on the side from which the wind blew at the time the spores spread."

In this connection it is worthy of note that we know of only one commercial orchard around which the cedars have been destroyed within a radius of about one mile. This orchard suffered from a very severe rust infection in 1912, and the owner spared no effort to follow out our recommendations as to cedar tree destruction. By the spring of 1914 there appeared to be no cedars within three-fourths of a mile, and there were not many within a mile of this orchard. During the summer of 1914 a large number of the commercial orchards in that section were visited, and the amount of rust in the above mentioned orchard was very small, as compared with the others. There was a scattered infection throughout the orchard, but that was to be expected.

We have been recommending that all cedars be cut for a radius of one mile around orchards, and from the records at hand the range does not appear to have been set too far. Records from one orchard around which the owners felt that cedar cutting had been quite well done show first, that considerable of the foliage on Rome Beauty trees had ten or more rust spots per leaf; second, that many of these leaves

were falling about the 1st of August; third, the nearest cedar trees were about 2300 feet from these Rome Beauty trees, and it is likely that most of the infection came from trees which were at least three-fourths of a mile away. The cedars were on slightly elevated ground, but not much above the orchard level. Observations in a number of other orchards indicate that a half mile cedar free range is not sufficient to prevent serious infection under West Virginia conditions. When even a very small percentage of the leaves have ten or more rust spots each, the infection is considered serious and a glance at Tables II and III will convince almost any reader that we have set our present limit several spots too high.

Some additional facts in regard to the range of infection have been given on page 30.

DESTRUCTION OR PREVENTION OF RUST GALLS ON CEDAR AS A MEANS OF CONTROL.

Cedar trees around a house are sometimes highly valued and the owners often desire to remove the rust galls instead of destroying the trees. It is possible that this practice may be effectively carried out in some cases, but it is a most tedious operation, and must be repeated year after year if good results are to be secured. We have records of several cases where it has been tried and abandoned. A man will usually revise his ideas as to the value of a cedar tree by the time he has spent ten to fifteen hours picking rust galls from it.

The spraying of cedars as reported by Heald (1909, p. 112) would doubtless be far more practical for the treatment of cases of this kind. This department has not conducted any experiments in the spraying of cedar trees.

SUSCEPTIBILITY OF APPLE VARIETIES.

Many lists have been published, giving data on the susceptibility or resistance of different varieties as they have been observed in various sections of the country. Table XXI gives some of the more important varieties and their susceptibility as listed by different states. Four signs are used to indicate varying degrees of susceptibility or immunity. 3 indicates susceptible, 2 indicates moderately susceptible, 1 indicates resistant, 0 indicates immune.

TABLE XXI.—*Susceptibility of apple varieties to rust as reported by different states.*

	Alabama	Connecticut	Delaware	Indiana	Iowa	Maryland	Massachusetts	Minnesota	Nebraska	New Hampshire	New York	North Carolina	Rhode Island	Pennsylvania	South Carolina	Virginia	West Virginia	Wisconsin
Arkansas Black			0			1						1					0	
Baldwin		1					1				1		1				0	
Ben Davis			1		3		1		1				1			3	2	
Black Twig	1		0													1	1	
Bonum			3									3				3		
Fameuse					1	3												1
Fallawater			3									3						
Grimes	2	1	3	1	3	1			1						3	1	1	
Jonathan	3			3	1				3					3		3	3	2
Maiden Blush	1		1			3			1								1	
Northern Spy																3		
N. W. Greening		1														1	2	1
Red June	3		0						3			3			3			
Red Astrachan	1		0			1	1		1				1					
Rome	3		0	3		3						3		3			3	
Shockley	3											3			3			
Stayman			0									1				1	0	
Wealthy		3		3	3	3	3	3	3	3			3				3	3
Winesap	1					1			1			1				1	0	
Yellow Transparent			0			1	1		1				1				0	
York Imperial	2											1		3		3	3	

Some varieties are listed as susceptible in one state and resistant in another. While there is undoubtedly some variation due to the difference in location, we are inclined to think that the judgment of the individual as to what constitutes resistance or susceptibility is a more important factor. Observations made upon single trees are sometimes misleading, since noticeable variation is often apparent among trees of the same variety. Different periods of rust infection may also give rise to confusing data, because the leaves of one variety may expand more quickly, or have a shorter period of susceptibility than the leaves of another variety.

From the data at hand we would give the following list for West Virginia:

Susceptible	Moderately Susceptible	Resistant	Immune
York Imperial	Ben Davis		Baldwin
Rome	N. W. Greening	Black Twig	Winesap
Wealthy		Grimes	Ark. Black
Jonathan		Maiden Blush	Stayman
			Yellow Transparent

SUMMARY AND CONCLUSIONS.

The meteorological conditions which help to bring about apple rust infection should receive further careful study. This laboratory is conducting some investigations along that line.

Apple leaves are susceptible only when young, and a destructive rust infection is not likely to take place after the first week in June, at this latitude.

A severe rust infection results in deformed fruit, a general reduction in size of fruit, and great loss of vigor on the part of the tree. There is a very distinct relationship between the number of rust spots on a York Imperial apple leaf and the length of time the leaf is retained by the tree.

This disease may be controlled by the use of spray materials, but it seems impracticable for the commercial orchardist.

The destruction of cedar trees has been found an effective means of control; but the work must be thoroughly done; and, under most conditions we believe that the cedar-free area should cover a radius of at least one mile around an orchard. The cost of cutting out cedars has been found to be comparatively small. An area including 1113 acres was cleared at an expenditure of $532.68, which was less than 48 cents per acre.

There is extreme range of susceptibility among apple varieties, and even different trees of the same kind show appreciable variation.

The detailed records covering our work on this disease are on file at this Experiment Station, and access may be had to them by anyone interested in work along that line.

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